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A
SYSTEM
OF
Experimental PHILOSOPHY,
Prov'd by
MECHANICKS.
WHEREIN

The *Principles* and *Laws* of *Physicks*, *Mechanicks*, *Hydrostaticks*, and *Opticks*, are demonstrated and explained at large, by a great Number of curious Experiments: With a full Description of the *Air-Pump*, and the several Experiments thereon: As also of the different Species of *Barometers*, *Thermometers*, and *Hydrometers*; as shewn at the publick Lectures in a Course of *Mechanical* and *Experimental Philosyphy*. As performed

By J. T. DESAGULIERS. M. A. F. R S.

Illustrated with several Copper Plates.

To which is added,

Sir *Isaac Newton*'s Colours: The Description of the condensing *Engine*, with its *Apparatus*: And ROWLEY'S HORARY; a *Machine* representing the Motion of the *Moon* about the *Earth*; *Venus* and *Mercury* about the *Sun*, according to the *Copernican* SYSTEM.

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TO

Sir Richard Steele.

SIR,

YOUR continual Care of me from my Infant Years has been so remarkably Generous, that I should be guilty of the deepest Ingratitude

tude in the World, did I not lay hold of all Occaſions of acknowledging the many and great Obligations I have to you.

I therefore humbly Preſent to You the following *Treatiſe*, containing the ſeveral *Philoſophical Experiments* ſhewn by Mr. *Deſaguliers* in his publick *Lectures*, which I have carefully collected, and that *Gentleman* approved of.

A Work ſo Curious cannot fail to give extream Pleaſure and Satisfaction to all *Gentlemen* who are Lovers of the moſt uſeful Part of *Philoſophy*, [the Experimental] eſpecially thoſe who have been preſent at theſe Courſes of Mr. *Deſaguliers*, as I my ſelf have conſtantly been.

But as my ſucceſsful going through theſe Courſes, has been

been entirely owing to Your Munificence and Bounty, ſo I know of no one who has ſo great a Right to this *Treatiſe* as Your Self, from whoſe Generoſity it derived its Being.

It flys then to You for Protection, who have merited ſo much from Mankind; and whoſe NAME will ſhine for ever Bright amongſt thoſe of the BELLE LETTRE: This will be an Honour to Mr.

DE-

DESAGULIERS, whoſe Experiments they are; but particularly ſo to,

SIR,

Your moſt obedient,

and moſt faithful Servant,

PAUL DAWSON.

DESAGULIERS, whose Experiments they are; but particularly so to,

SIR,

Your most obedient,

and most faithful

Servant,

PAUL DAWSON.

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THE PREFACE, OR Advertisement to the READER.

By J. T. Desaguliers, *M. A.* &c.

I *Think my self obliged to give an Account of the following Lectures, to serve as an Apology for their appearing before I designed to publish them.*

It is about sixteen or seventeen Years since Dr. John Keil *(the present Savilian Professor of* Astronomy*) first gave Courses of Ex-*

perimental Philosophy in Oxford; *and being desired by some of his Auditors to give them something in Writing upon that Subject, he wrote a few Papers to serve them as* Memorandums. *I was his Scholar at the last Course he gave before he went beyond Sea; but could not then get those Papers. Some time after he was gone, I was desired by some of my Friends (who knew that I had applyed my self to Experimental Philosophy) to give publick Courses, and then my Auditors desired to have written Lectures. I endeavoured to get Dr.* Keil's *Lectures, (as they were called) which when they were brought me I found altered according to the Fancy and Number of the Transcribers. Some Papers relating to Motion seem'd to be translated from Sir* Isaac Newton's Principia, *the Optical Lectures from Dr.* Gregory's Catoptricks, *and some of the Hydrostatical Propositions I took to*

 be

be put in the Method in which they were by Dr. Keil. *I then corrected the Faults, added other Propositions so as to make the Book as big again as before, that it might agree with the Lectures I then gave, and drew ten Tables of Figures which I got engraven in Copper Plates, that every Auditor that was at the Pains to transcribe the Lectures, might have an Impression of the Plates, to save himself the Trouble of drawing the Figures. Mr.* Dawson *(a young Man whom Sir* Richard Steel *had put under my Care) took a Copy of the Lectures above-mentioned, that they might be of Service to him when he went thro' my Courses, and they were afterwards sold and published without my Knowledge. But as the Booksellers have made me Satisfaction, and purchased the Copy of me, I have looked over the whole Book, and corrected every Error therein; because I was unwilling that those who*

buy

buy it should find it any wise imperfect, and desirous that it might be of use to such as go thro' Courses of Experimental Philosophy.

The Reader therefore is desired to correct the Faults with his Pen, as the Errata *direct, before he begins to read the Lectures.*

ERRATA.

PAg. 7. Lin. 3. r. *Ingredients.* l. 21. r. *or coeval.* p. 8. l. 10. r. *Matter at first pull'd.* p. 14. r. *to weigh twelve.* p. 17. l. 19. r. *Fulcrum* B C. p. 18. l. 19. r. *one Pound at* A *will sustain.* p. 19. l. 19. dele *not* p. 22. l. 1. r. *fix'd Point.* p. 24. l. 7. r. *Piece, as* D. l. 8. r. C C. *at the other End bearing on two Pieces that are higher.* l. 10. r. *radius of the Body.* p. 30. l. 4. r. *lance is to the Weight of the Ballance.* p. 31. l. 4. r. *Weight of.* p. 33. l. 15. r. *fix'd Point.* p. 34. l. 8. dele K E G. p. 42. l. 23. r. G O *the Velocity.* l. *ult.* r. *to* G F. p. 43. l. 2. r. E F O & G O *which.* p. 44. r. *pondus, and of.* l. 16. dele *of the second kind.* p. 45. l. 6. dele L. l. 10. r. *Power must be to.* l. 18. r. Helices. l. 19. r. *Velocity.* l. 22 r. *is longer.* p. 47. l. 7 & 8. r. *an endless Screw.* p. 53. l. 21. r. *pushed (by.* l. 22. r. *Force) towards.* p. 54. l. 1. r. *the Force impress'd.* l. 3. r. *double* Momentum, *or Quantity of Motion.* p. 55. l. 13. dele *with.* l. 17. r. *times. When.* ibid. dele (;) after *descends.* l. 23. r. *instant of time, as the.* p. 56. l. 7. dele *with.* l. 11. r. *as the times.* p. 62. l. 1. r. *Motion.* l. 13. r. *upon* A *in the Direction* C A. p. 63. l. 20. r. B *comes to* A. l. 21. r. *the Boat* A. p. 65. l. 14. r. *forwards, it.* p. 72. l. 12. r. *towards each other with.* p. 82. l. ult. dele K E D. p. 84. l. 7. r. *above the Superficies.* p. 86. l. 11. r. *exceeds.* l. 17. r. *immediately over.* l. 19. r. *to be nearly.* l. ult. r. *to press above.* p. 87. l. ult. r. *Prisms or Columns.* p. 88. l. 1. after B r. F. l. 11. r. *exactly fitted.* l. 13. r. *Sides of the Cylinder, let* a E *be.* p. 90. l. 15. & 91. l. 6. dele K E D. p. 96. l. 17. r. *mount.* l. ult. r. *exceeded by it.* ibid. for *Surface* r. *Height.* ibid. f. *would* r. *when they would.* p. 97. l. 3. r. *immers'd.* f. *heavier* r. *lighter.* l. 9. r. *is to the.* l. 14. dele *to.* l. 15. dele K E D. p. 100. l. 5. r. E A D F. p. 103. l. 12. r. *will continue.* l. 22 & 23. r. *after having pump'd out the Air.* p. 104. l. 11. r. *external.* l. 21. r. *of* 28, 29, *or* 30 *Inches.* l. ult. r. *less than* 28 *Inches.* p. 105. l. 10. r. C P. *will be.* l. 11. r. C *shall sustain.* l. 22 & 23. r. *as before, is Gravity acting partly.* p. 106. l. 1. r. *depends.* l. 11 & 12. r. *of* 28 *or* 30 *Inches.* p. 107. l. penult. f. *is* r. *would.* before *to* r. *be.* p. 108. l. 7 & 8. r. 29 *or* 30 *Inches.* l. 10, 11, 12. *remain at* 28, 29, 30, *or* 31 *Inches* p. 109. l. 10. r. *the different Gravity of the Air, and therefore foretells foul or fair Weather.* p. 111. l. 13. r. *longer Tube more than in the shorter.* l. 17. r. *recurved Tube.* p. 113. at the end of l. 2. add, *That shews that Pillars of Air of equal Basis and equal Heights balance one another.* l. 3. r. ☿ *will rise by sucking it thro' a Crane or Syphon, but not.* l. 4. r. *Height as Water.* l. 17. r. *restitutive.* p. 117. l. 3. r. *restitutive.* p. 118. after *last line,* r. *if they be let down too suddenly.* p. 120. l. 1. r. *Tube.* p. 121. l. 16. r. *the Syringe is left.* p. 122. l. 5. r. *made use of it (but according to the Alterations that I have made in it since it has been in my Possession.)* p. 124. f. *Cleft* r. *Close.* p. 125. l. 19. f. *left* r. *soft.* l. 23. r. *let the soft Leather.* l. 24. r. *that by the Pressure.* l. ult. dele *the more.* p. 129 l. 7. r. *hanging a Weight.* p. 130. l. 6. r. *will not subside.* l. 12. r. *flaccid Bladder.* p. 134. l. 5. r. *the Cock.* l. 9. r. *Hygrometers.* p. 135. l. 8. r. *fitted.* l. 10. r. 31 *Inches.* l. 11. r. *at* 30, *sometimes at* 29. l. 12. dele *sometimes it will sink to* 27. l. 15 & 16. r. *to the Quantity of Matter, it is.* p. 136. l. 10. f. *Society* r. *Academy.* l. 13. f. *in* r. *on.* p. 139. l. 1.

f. *String.*

ERRATA.

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A SYSTEM OF Experimental PHILOSOPHY, PROV'D BY MECHANICKS.

NATURAL *Philosophy* is that Science which gives the Reasons and Causes of the Effects and Changes which naturally happen in Bodies.

And that we may not be deceived by false Notions which we have embraced without Examining, or that we have received upon the Autho-

rity of others; we ought to call in Queſtion all ſuch things as have an Appearance of Falſhood, that by a new Examen we may be led to the Truth.

This Examen is to be made by Suppoſitions, which we may rely upon, when they agree with Experiments; but if only one Experiment is contrary to any Suppoſition, that Suppoſition muſt be rejected, and a new one made, till we find that it agree with all other Experiments. Therefore, we muſt not go about to define a Cauſe, unleſs we know its Effects; or lay down a general Propoſition, if we doubt of any of the Particulars it comprehends, leſt we run into Errors and take things for granted, which have been found contrary to Experiments and Mathematical Demonſtrations. An Inſtance of this may be given in what has formerly been ſaid about Heat and Cold, *viz.* That Heat unites homogeneous Bodies, and ſeparates heterogeneous Bodies; and that Cold unites heterogeneous Bodies, and ſeparates homogeneous; all which we find to be falſe in ſeveral Inſtances.

1. Mix and Melt *Gold* and *Silver* together, and the Fire will not ſeparate them; neither will

it

it ſeparate two Parts of *Braſs* mixed with one of *Copper*.

2. It rather unites, than ſeparates ſuch heterogeneous Bodies as have an aptneſs to Coalition; as in making *Plaiſters* and *Ointments*, &c. and in uniting *Salt-Petre* and *Aſhes*, into ſo durable a Body as *Glaſs*.

Fire only diſlocates the Parts of Bodies, and ſubdivides them into minute Particles, without reſpect to their being Homogeneous or Heterogeneous; which is evident in boiling *Water*, or other Liquors, whoſe Steams condenſe to the ſame Subſtances again. And in *Diſtillation*, where all the Parts are in a Confuſion upon the ſlackening of the Heat, or the Parts receding from it when driven into the Receiver, they take Place according to their *Specifick Gravities*. Such Parts alſo, as are moſt eaſily Separated, are ever carried firſt off as in the Diſtillation of Man's *Blood*; firſt *Water*, then *Spirits* and *Salt*, then *Oil*. The *Earth* and *Alkali* remain together, becauſe of an equal Degree of Fixedneſs, tho' Heterogeneous. Cold does not always unite heterogeneous Bodies, but ſeparates 'em; as in the *Urine* of healthful People it cauſes a Sediment, which is again diſper-

ſed, and made to diſappear by Heat. And by Froſt, the Strength of *Wine* is ſeparated, and unfrozen in the middle of the Veſſel. *Straw*, *Duſt*, *Wood*, &c. are no farther united in *Ice*, than as they are fettered up in the frozen *Water*.

By *Elements*, the *Philoſophers* meant moſt *Simple Bodies*, of which they ſaid, all the Bodies we ſee, are made, and which may be extracted from all Bodies. But they have been miſtaken in conſtituting their *Elements*, becauſe they did not ſo much explain the Nature of things, as what Senſes thoſe things excite in us.

They that conſidered things as they affect the Sight, made only two *Elements*; the *Lucid* and *Opaque*; tho' they gave but a blind Account of *Light* and *Colours*.

The four *Elements* that have obtained ſo long, only expreſſed the ſeveral ways that our Touch is affected; for thoſe that eſtabliſhed them, conſidering *Heat* and *Cold*, *Moiſture* and *Dryneſs*, ſuppos'd 'em the Properties and primary Qualities of all Bodies, and accordingly conſtituted four *Elements*.

The *Earth*,	they ſuppoſed	*Cold* and *Dry*,
The *Water*,		*Cold* and *Moiſt*,
The *Air*,		*Hot* and *Moiſt*,
The *Fire*.		*Hot* and *Dry*.

To illuſtrate this Doctrine, and prove that theſe are in, and may be extracted from Bodies; they uſed to burn a piece of *Green-wood*, and call the *Coals* and *Flame*, *Fire*; the *Sweat*, *Water*; the *Smoak*, *Air*; and the *Aſhes*, *Earth*.

But theſe cannot be *Elements* according to their Definitions, for they are not Simple and Unchangeable, but may be altered and produced *de novo*; the *Smoak*, which they call'd *Air*, may be condenſed into a Liquor; the *Fire* is only *ſubtile Matter* in a rapid Motion.

The *Moiſture* will produce *Caput mortuum*, and *Oils*. The *Aſhes*, which they call *Earth*, will make *Glaſs*.

Beſides, ſeveral things are not reducible into four heterogeneous Bodies, as *Gold*, *Silver*, *Diamonds*, common *Glaſs*, *Venetian Talk*. Tho' They and the *Chymiſts* have often endeavour'd it, and if they could do it, yet they could

could not prove their *Elements* to be unmixed, becauſe Experiments ſhew the contrary. The *Chymiſts* Principles are *Salt*, *Sulphur*, and *Mercury*, which they call their *Elements*, but as erroneouſly; for theſe cannot be had from *Glaſs*, *Gold*, *Diamonds*, *Sand*, &c. or may be deſtroyed and produced *de novo*.

Mr. *Boyle* affirms, that *Quick-ſilver* has been turned into *Water*, and *Sulphur* altered; and that the *Mercuries*, *Sulphurs*, and *Salts* of the *Chymiſts*, are not *Similar Bodies*; whereas, to be *Elements*, each ought not to differ from thoſe of the ſame Name, more than Drops of *Water* do from one another. Others add to theſe three Principles, *Caput mortuum* and *Phlegm*; that is, *Water* and *Earth*; but theſe five are produceable even from *Water* alone; and Art can of two *Elements* compound a Body, as durable as any in the World, *viz.* *Glaſs* made of *Aſhes*, that hath only *Salt* and *Earth*.

The Doctrine of *Acids* and *Alcali's*, is as faulty as the foregoing; for none of theſe Hypotheſes can account for Firmneſs and Fluidity, the *Phenomena* of the *Load-ſtone*, the Formation of a *Fœtus*, *Sounds*, and a thouſand other things that fall under the Notice of a *Philoſopher*. And

And as long as the *Chymiſts*, or any other *Philoſophers* endeavour to explain things by a Number of mixed Ingedients in a State of Reſt, they will be deficient; ſince the greateſt Part of the Affections of Matter, and conſequently the Phænomena of Nature, ſeems to depend on the Motion and Contrivance of the ſmall Parts of Bodies.

That *Philoſophy* therefore is the moſt reaſonable, which teaches,

1. That the Matter of Natural Bodies is the ſame; namely, a Subſtance extended, diviſible, and impenetrable.

2. That ſince there can be no Change in Matter, if all its Parts were at Reſt among themſelves; to diſtinguiſh the general Matter of the Univerſe, into a Variety of natural Bodies, it muſt have Motion, in ſome or all of its Parts, which muſt be variouſly determined. And tho' it is manifeſt to Senſe, that there is a local Motion in Matter; yet Motion is not included in the Nature of Matter, Cœval with it; Matter being as much Matter when at reſt, as when in Motion. And tho' it be wholly diſputed, how Matter came by that Motion, by thoſe who acknowledge not an Author of the Univerſe; yet ſince a Man is not the

worſe

worſe Naturaliſt for not being an Atheiſt; we allow that the Origine of Motion in Matter, as well as of Matter it ſelf, is from GOD.

3. That local Motion is the chief Principle amongſt ſecond Cauſes, and the chief Agent of all that happens in Nature. Bulk, Figure, Reſt, Situation, and Texture, being the Effects of Motion; as in a *Watch* or *Clock*; it is Motion therefore that makes all uſeful.

DesCartes ſuppoſes Matter as fixt, let it be pulled into pieces of what Shape any pleaſes to imagine; we will ſay Cubick, as moſt obvious. Then every one of theſe Parts being turned ſwiftly round its own Center, and alſo about another Center common to all the Parts; the Corners muſt be wore off of ſeveral of theſe Parts, and a fine Duſt be made by that Friction. The ſmall Duſt is the *Materia Subtilis*, or firſt *Element*; The Cubes that have been rubbed round into Globules, make the ſecond *Element*, of not ſo ſwift a Motion as the firſt, which is agitated between the Interſtices of the Globules; The Cubes that have not loſt their Shape, by having their Angles much broken, make the third and unactive Element.

To

To illuſtrate this Hypotheſis, take Cubes of *Clay*, and ſhake them together in a round Box, till ſome of them are become pretty near round; the Duſt repreſents the *Materia Subtilis*, the roundeſt Pieces the *Globuli* of the ſecond *Element*, and ſuch as have not much changed their Shape, the third *Element*.

Tho' this Hypotheſis may ſeem ingenious enough at firſt, yet if duly weighed it will appear, inconſiſtent with Experiments, and the Laws of Motion. Take a Dozen or two of Cubes of any bigneſs, for Example, ſome of an Inch, ſome of half an Inch; and having ty'd a Thread to each, and all the Threads to the Center of a round Table, made to turn eaſily upon a *Pivot*; (*as the Table of Plate 3. Fig. 5.*) as ſoon as you have given the Table a ſwift Motion round its Center, all the Cubes will recede from the ſaid Center, and ſtretch the Thread; which ſhews they cannot grind each other into Globules; ſince by reaſon of their centrifugal Force, by which they are whirled round one common Center, they muſt recede from each other.

If we ſuppoſe any ambient Surface to make a Reſiſtance (as the Box does in the Caſe of the

Cubes of *Clay*) then either the Cubes touch one another before the Motion begins, or they do not. If there be a *Plenum* (as *Cartes* believes) the Cubes touching one another in all the Parts of their Surfaces, cannot grind each others Corners off by a particular Motion in each Cube; but muſt all move together, and become one Body, as before the rude Lump of Matter was ſuppoſed diſtributed into Cubes. If there be any Spaces between the Cubes, there muſt be a *Vacuum* (which *Cartes* denies) or that Space muſt be filled with a *ſubtile* yielding *Matter*; which would be ſuppoſing the *Materia Subtilis*, before we ſuppoſe it, which is abſurd; or denying Matter to be Homogeneous, which is before Suppoſed.

That Firmneſs and Fluidity, Heat and Cold, Odours, Savours, Colours, and Sounds, depend upon the Shape, Size, and Motion of the Parts, may appear from two cold Things producing Heat; as Oil of *Tartar per Deliquium*, poured on Oil of *Vitriol*, will cauſe it to boil and fume, *&c.*

A ſolid Body will loſe its Smell and Firmneſs, by the Infuſion of one Liquor, and recover both

by

by the Infusion of another. As *Camphire* will be dissolved, and lose its Scent, by the Infusion of Oil of *Vitriol*; but by pouring on Water, the Smell and Solidity will be restored. *Sal Armoniack* dissolved into *Water*, makes a Mixture colder than each is singly.

Water will be so rarified by means of an *Æolipile*, as to become lighter than Air; and if the Hand be held near the Mouth of the *Æolipile*, the *Water* that strikes on the Hand, will again be condensed, and become as heavy as at first. Several more Experiments prove this Hypothesis. Now if Firmness, Fluidity, Heat and Cold, Smells and Savours, depended only upon a Mixture of Ingredients, as some affirm; then first, two cold Things would continue Cold when mixt. Secondly, A Liquor without Smell would not give Scent to another Liquor. Thirdly, Two Fluids when mixed, would continue Fluid; but the contrary is shewed by several Experiments.

The Extension of Matter, and its Impenetrability, are self-evident; and its Divisibility appears from the Ductility of *Gold*; for an Ounce of *Gold* will guild a large Piece of *Silver*, which when drawn into Wire, will likewise then be all o-

ver guilded, tho' the Wire be ſo ſmall, as to reach above A Hundred and fifty Miles. See an Account of the Ductility of *Gold*, given in ſquare Lines, in *Clarke*'s *Rohault*, Part 1. Chap. 9.

A *Candle* ſeen by a whole Multitude, ſhews the Diviſibility of Matter to be infinite, becauſe the Rays of Light muſt enter every Man's Eye; for unleſs thoſe fine Parts of the Fluid made an Impreſſion upon the *Retina* of the Eye, the *Candle* would not be ſeen.

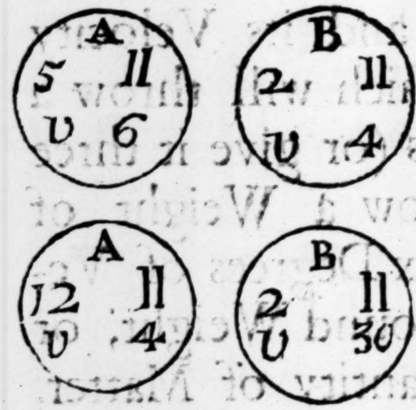
MECHANICAL PRINCIPLES.

THE Quantity of Motion which we ſometimes call the *Momentum*, or ſometimes ſimply Motion, is that Force or Energy by which a Body changes its Place. Therefore we ought to take care leſt we ſhould confound Motion and Velocity together; becauſe ſome People think, one Body to have more Motion than another, when it moves faſter, altho' it ſhould be leſs than the

other

other; whereas it may only be ſaid to have more Velocity, Celerity, or Swiftneſs. But Motion is always eſtimated from a Conſideration of the Quantity of Matter in a Body, and its Velocity together; for the ſame Force which will throw a Two Pound Weight three Yards (or give it three Degrees of Velocity) will throw a Weight of One Pound ſix Yards (or give ſix Degrees of Velocity) and therefore the One Pound Weight, or the Body which has the leaſt Quantity of Matter, cannot be ſaid to have more Motion in it than the Two Pound Weight (or the Body which has twice the Quantity of Matter) tho' it moves as faſt again: For if we conſider, that when the Force or Motion, which is able to carry one Pound ſix Yards, is applied to a Two Pound Weight, each Half of the Two Pound Weight has an equal Share of this Motion (now diſtributed) it will be plain, that the Two Pound Weight ought to be carried but three Yards. The Quantity of Motion may be increaſed, either by keeping the ſame Quantity of Matter, and augmenting the Velocity, or by keeping the ſame Velocity, and increaſing the Quantity of Matter, or by increaſing both; and therefore the abſo-

absolute Force by which Bodies are moved, is known by the Multiplication of their Celerities into their Matter or Weight.



As for Example, in the two Bodies, A and B, let A be five Pounds, and B two Pounds; let the Velocity with which A is moved be six Degrees, and let B have four Degrees of Velocity, then the Degrees of Motion in A will be thirty, and B will have eigth Degrees of *Momentum*, or Motion.

Suppose A to have twelve, and B two Pounds; let A have four Degrees of Velocity, and B thirty, the Quantity of Motion in A will be forty-eight, and in B 60. From hence it follows, that any little Body may have its Motion equal to the Motion of any great Body, *viz.* If the Velocity of the little Body is so much greater than the Velocity of the great Body as the Quantity of Matter in one is greater than the Quantity of Matter in the other, (*i. e*) when both Bodies have their Velocities reciprocally proportionable to their Weight, their *Momenta*, or Quantities of Motion

tion will be equal. As for Example, let A be fifty Pounds, and B two Pounds; let the Velocity of A be 3, and of B 75; now 50 has the same Proportion to 2, as 75 has to 3; and therefore the Quantity of Motion in A, which is 3 times 50, or 150, is equal to the Motion in B, which is twice 75, or 150. If the Velocities of Bodies are equal, their Quantities of Motion will be as their Matter, which is contained in them; and therefore since all Bodies (abstracting from the Resistance of Air) descend equally fast; the Motion which Bodies acquire by their Gravity in descending, will be as their Quantity of Matter. As a *Feather* descends as fast in *vacuo* as a Pound of *Lead*; but suppose the *Lead* 1000 times heavier than the *Feather*, the *Momentum* of the *Lead* will be 1000 times greater; Gravity is the Cause of the Descent of both: Therefore there is 1000 times more Gravity required to make the *Lead* descend, than the *Feather*; so that the *Feather* which has 1000 times less Matter than the *Lead*, may descend with as great Velocity as the Lead, the *Momentum* of the *Lead* being 1000 times greater than it.

And

And consequently, since all Causes are proportional to their Effects, the Gravity of Bodies, which produces their Motion downwards, will likewise be proportional to the Quantities of Matter in Bodies; and therefore the Quantity of Matter in any Body, may be estimated by its Weight; and therefore if an Inch of *Lead* be 6 times heavier than an Inch of *Wood*, there must be 6 times more Matter in the Inch of *Lead*, than in the same bulk of *Wood*; and hence may be drawn a good Argument for a *Vacuum*. For tho' we should grant the Existence of *Materia Subtilis*; yet still the Question will return, how this Matter comes to be so fine, but by having void Spaces?

We must then also suppose the Pores of all Bodies to go in a strait Line, and Horizontally; and they must always be supposed to move in the same strait Direction; otherwise the *Materia Subtilis* would be reflected, and so consequently not fill up all the Pores; sometimes hindering, and sometimes not hindering the Gravity of a Body; so that the same Body would be more or less heavy, as its Pores lay in a horizontal, or contrary Position. The whole Effect of *Mechanical*

nical Engines, is to diminiſh the Velocity of the Weight to be raiſed, ſo that the Quantity of Motion it will have, may be no more than the Quantity of Motion in the Power that raiſes the Weight.

Suppoſe a Man can raiſe by his Strength, without an *Engine*, only ten Pound Weight, with a determinate Degree of Velocity; it's not poſſible for him with any *Engine* to raiſe a hundred Pound with the ſame Velocity; yet by the Application of an *Engine*, a Man can raiſe a Hundred Pound, with the 10th Part of that Velocity.

Plate 3d. Fig. 1.] Now all that the *Engine* does, is to diminiſh the Velocity of the *Pondus*, ſo as to make its Motion no greater than the Motion of the Power raiſing it, as may be ſeen in the *Vectis*, which we ſuppoſed as a *Mathematical Rigid*, or inflixible Line, only moving round the Point C, which is called the *Fillerum*, B C, and C A are called the *Brachia*. In the *Statera*, the two *Brachia*, (tho' the one be longer than the other) are equally heavy; and conſequently B C keeps in *Equilibrio* C A, which is divided into 10 Lengths, each of which is equal to B C. Let Q be the Weight which is to be found out

 by

by hanging any given Weight P upon the *Brachium* C A, and moving it up and down, till it makes an *Equilibrium*, you will find out the Weight Q; for ſince P in the Diſtance 5, is *Equiponderate* with Q, it follows that Q is the *Quintuple* of P, as is here Demonſtrated.

Now ſuppoſe that if the *Brachia* are equal, a Man could only raiſe ten Pounds; then I ſay, that if you alter the *Brachia*, and make C A 10 times longer then B C, he can by this *Engine* raiſe a Hundred Pound; for, becauſe B C, is but the 10th Part of C A, the Space B b will be but the 10th Part of A a, and conſequently when B moves, it will have but the 10th Part of the Velocity of A; but by Suppoſition the Force of A is ſo great, as to raiſe by that Velocity a Body of Ten Pounds; therefore it will raiſe by the 10th Part of that Velocity a Body of a Hundred Pounds. From hence it follows, that the Weight at A will weigh 10 Pounds, placed at B; for, becauſe A a is 10 times greater than B b, the Velocity of One Pound at A, will be 10 times greater than the Velocity of Ten Pounds at B; and therefore their Quantities of Motion will be equal, they being reciprocally proportional to

 their

their Weight. Since then, the two Bodies have equal *Momenta*, or equal Forces that moved them; these Forces being contrary, or acting contrary, the one to the other, will destroy one anothers Motion, and keep an *Equilibrium*.

A Point in any Body so placed, that all Matter on every Side Gravitates equally, is called the *Center of Gravity* of that Body; the *Center of Gravity* is not always the *Center of Magnitude*, as in the *Statera Romana*, where it's not required that the short *Brachium* should have an equal Quantity of Matter to what the long one has.

The *Center of Motion* is that Point, round which if a Body moves, every Point of it describes Circles, whose Centers are in the *Center of Motion*. The *Center of Gravity* of all Bodies descends as much as it can; and if a Body be suspended by its *Center of Gravity*, it will not retain any given Position; for in that Case the *Center of Gravity* cannot descend. If the *Center of Gravity* be different from the *Center of Motion*, and then if the *Center of Gravity* be put out of the Perpendicular, the Body will turn round till the said *Center of Gravity* be just un-

der the *Center of Motion*, for then it has defcended as much as it can.

Plate 3d. Fig. 2d. Let A B be a Beam, whofe *Center of Motion* at m is above the *Center of Gravity* c, if it were turned out of the horizontal Pofition, the *Center of Gravity* muft afcend, Suppofe to k; and therefore if the Body be left to it felf, 'twill turn round, till the *Center of Gravity* comes again to its former Pofition.

In a Balance the *Axis*, and the *Center of Motion* is a little above the *Center of Gravity*; for if it were exactly in it, it would retain any given Pofition; but by being above it, the Beam of the Balance when in *Æquilibrio*, muft fettle it felf in an horizontal Pofition.

The *Center of Motion* may be put below the *Center of Gravity*, but if you move them ever fo little out of an exact Perpendicular, the Scales will not be in an *Equilibrium*; but as foon as you let the Balance hang freely, the *Center of Gravity* will get below the *Center of Motion*.

MECHANICAL POWERS.

DEFINITIONS.

1. A *Weight is any Body to be raiſed, or mov'd.*

2. *A Power is that Force by which a Weight is raiſed, whether it be a Force that Draws, or Puſhes, or Strikes, or a Weight which Gravitates; for a Weight is a Power, in reference to the heavy Body which it may move.*

3. *The Abſolute Gravity of a Body, is its Endeavour to deſcend in a free Medium.*

4. *The Relative Gravity of a Body, is its Endeavour to deſcend when it touches, ſomething elſe beſides the Parts of the Medium; and that is always leſs than the Abſolute.*

5. Equilibrium, *is, when there is the ſame Quantity of Motion in the Power, as there is in the Weight; becauſe theſe Motions being contrary, the one deſtroys the other.*

6. *The Center of Motion*, Fulcrum, *or first Point, are all the same.*

7. *The Line of Direction of a Power or Weight, is that in which it endeavours to move. In a heavy Body the right Line, by which it endeavours to descend. In a Power, the right Line by which a Power draws or pushes a Weight,* (Plate 1. Fig. 1.) *If C draws A over B, B C is the Line of Direction of the Power, and A D that of the Weight, by which it resists the Traction.*

8. *The Application of a Power to a* Vectis, *or* Leaver, *is the Angle which the Line of Direction of that Power makes with the* Leaver, *as the Angle A B E in* Fig. 2. Plate 1.

9. *The Distance of a Power or Weight is a Line drawn from the fixed Point perpendicular to the Line of Direction, as C F.* Fig. 2. Plate 1.

10. *In all regular and homogeneous Bodies, the* Center of Gravity *is in the* Center of Magnitude.

SUPPOSITIONS.

1. *We must suppose the Earth flat, because the greatest* Engines *are but as a Point, when compared with the Surface of the Earth.*

2. *When*

2. *When heavy Bodies fall freely, they make Lines perpendicular to the Earth, meeting in the Center of the Earth ; and those we are to suppose Parallel.*

3. *Tho'* Engines *are imperfect, we must suppose them perfect ; that by such a Supposition we may better find out what they'll do, as that Bodies are perfectly hard, smooth and homogeneous. Lines strait, without Weight, Thickness, or Flexibilily, and Cords extreamly pliable.*

AXIOMS.

1. *To raise a Weight with an* Engine, *the Velocity of the Power must be increased and that of the Weight lessened.*

2. *The* Center of Gravity *always descends as low as it can.*

3. *A Body can fall no lower than it is, unless its* Center of Gravity *descends.*

4. *If all the Weight of a Body was reduced into its* Center of Gravity, *it would move as before.*

Propo-

Propoſition I. Probleme.

How to make a heavy Body ſeem to riſe of it ſelf.

THE Body muſt be a double Cone of Wood, or any ſolid Matter, as in this Figure.

Set two long flat Pieces of Wood on a Table, croſſing each other at one end on another Piece (*Plate* I. *Fig.* 3.) as C C D, ſo as to raiſe them almoſt as high above the horizontal Plain at the other End, as is the Difference of the Radius at A, and that at B; then lay the Body A B A upon them at D, where they muſt meet in an Angle, and it will roul up to C, if the Diſtance C C be no greater than the Diſtance A A. The Reaſon follows:

When the Body is laid on at D, the *Center of Gravity*, which is in the middle of the Diameter B A, where it's cut by the *Axis* (*Plate* I. *Fig.* 3.) A A (becauſe the Body is Regular and Homogeneous) is higher than it is when the Body has rouled to C C. Now becauſe the *Center of Gravity* endeavours to fall as low as it can, the Body will roul to C C, where it's lower than it was before,

before, tho' its Supporters be higher, as will appear by holding a Thread horizontally from D to E; for if the Body touch the Thread when at D, it will be below it when it has rolled to E.

Prop. II. *Theoreme.*

What is ſaid of the Deſcent of a heavy Body, is to be underſtood of its *Center of Gravity*; becauſe unleſs the *Center of Gravity* can fall, the Body cannot fall, by the foregoing *Prop.* for the Body (*Plate* 1. *Fig.* 5.) A B C D, which ſtands upon the horizontal Plane F C, cannot fall towards F, where it inclines; becauſe its *Center of Gravity* E would riſe, which appears (*Fig.* 5.) by drawing the Arch E F about the Point B. But A B C D will fall, becauſe its *Center of Gravity* can fall, as (*Fig.* 6.) appears by Conſtruction.

SCHOLIUM.

Fig. 4.) Since the firſt Impulſe of an heavy Body downwards, is begun at its *Center of Gravity*, and that the *Center of Gravity* endeavours to get as low as it can; a heavy Body muſt endeavour to deſcend in a Line (called the *Line of Direction*, as E G, C O) drawn from its *Center of Gravity* to the Center of the

Earth, or *Centrum Gravium*, which is the loweſt Place; and if it can't move in the Line E G, by reaſon of the Interpoſition of a Plain, (ſo inclined as not to hinder the *Center of Gravity* from deſcending) 'twill fall obliquely by ſliding or rolling, ſo as to get into the *Line of Direction* C O, as faſt as it can.

COROLL. 1.

Hence alſo will the Body D ſlide, and the Body F roll upon the inclined Plane A B C (*Fig.* 4.) to get to the Line C O, Parallel to its *Line of Direction* E G.

COROLL. 2.

Fig. 5. and 6.) Hence alſo will Bodies ſtand firm upon an horizontal Plain, if their *Line of Direction* falls within their *Baſis*. Thus the Body of (*Fig.* 5.) will ſtand, and that of (6) fall. A Bowl will eaſily change its Place, becauſe its Baſe being but one Point (*Plate* 1. *Fig.* 7.) it's eaſy for the *Line of Direction* E G to fall out of it. This is the Reaſon alſo, why it's almoſt impoſſible to ſet a ſtrait Stick or a Needle upright upon a ſmooth horizontal Plane, becauſe that the

Lines

Lines of Direction E G fall out of their *Bases*. What is said of the *Center of Gravity*, may be also understood of the common *Center of Gravity* of two heavy Bodies, as we shall shew in the Example of the *Balance*.

Of the BALANCE.

Prop. I. *Theoreme.*

WHEN a *Balance* has its *Brachia* of the same Length and Weight, the Power and the Weight are equal.

Prop. II. *Probleme.*

To make an *Equilibrium* with an horizontal *Balance*, (*Fig.* 8.) Let the Weight D be to the Power E as the Distance C B of the Power to the Distance A C of the Weight; and so *vice versa*. Thus will the *Center of Gravity* be brought under the *Center of Motion*.

Prop. III. *Theorem.*

By increaſing the Velocity of the Power, the Velocity of the Weight is leſſened, as has been ſhewed in the *Statera Romana.*

Prop. IV. *Probleme.*

Knowing the Weight of two heavy Bodies applied to the Ends of a Balance *of known Length, to find upon that* Balance *the common* Center of Motion.

Let A B the *Balance* be twenty-four Inches long, the Weight D twelve Ounces, E ſix Ounces. To find the fixed Point whence the *Balance* being ſuſpended, the Weight will hang in *Æquilibrio.* Find a 4th proportional to 18 . 6 : : 24: which will be eight Inches for A C : that is, as 18 (the Sum of the two Weights) is to 6 the leaſt Weight, ſo is twenty-four Inches (the whole Length of the *Balance,*) to eight Inches or A C the Diſtance of the fixed Point from that End of the *Balance* which has the biggeſt Weight.

Tho' this is true in the Theory, yet it won't hold in the Practice becauſe (*Plate* 1. *Fig.* 9.) the *Balance*

lance A B, which we have ſuppoſed without Weight, can't be really ſo; becauſe the two *Brachia* are not of the ſame Weight. Hang the Weight F = to D + E at C, (which by *Axiom* 3.) won't alter the Effect of the two Weights D E. Then hang at I the *Center of Gravity* of the *Balance*, the Weight G = to the *Balance*'s Weight; then conſidering C I as a *Balance* laden with its two Weights, at its Ends C I, find out O the common *Center of Gravity*, as taught, *viz.* F + G : G : : C I : C O.

Prop. V. *Prob.*

Knowing the Length and Weight of a Balance, *which has at one of its Ends, a Body of known Weight; to find the fixed Point, about which the Balance and Weight of the Body ſhall remain in* Æquilibrio.

Length of the *Balance*	12	*Inches*,
Weight of the *Ball*:	16	*oz.*
Weight of D	8	*oz.*
Sum of the Weights	24	*oz.*
Half Length of the *Balance*	6	*Inches.*

find

find a 4th proportional to 24 : 16 : : 6 : which will be four Inches for A C; that is as the Weight of the Body together with the Weight of the *Balance*; so is half the Length of the *Balance* to A C, the Distance from the Weight of the Body to the fixed Point.

Prop. VI. *Prob.*

How to make a deceitful Balance, *which being empty and also laden with unequal Weights, shall remain in* Æquilibrio.

Fig. 11.) Let the Length A C be to B C as the Weight of the Scale E, to that of the Scale D. The *Æquilibrium* will be kept if the Scales are laden with Weights, that have the same *ratio* to one another, as 11 to 12; but the Fraud will be detected by changing the Place of the Weights.

Of

Of the LEAVER.

Prop. I. *Theoreme.*

THE *Leaver* is reducible to the *Balance*; the Weight an animate Power being the ſame as the different Weights in the *Balance*, and the fixed Point the ſame as the *Center of Motion*.

Prop. II.

The three firſt Propoſitions of the *Balance* are true concerning the *Leaver*. (*Fig.* 12, 13, 14, 15.) C is the *Fulcrum*, or fixed Point; E the Power applied at B and D, the Weight applied at A.

Fig. 12. Is a *Leaver* of the firſt Kind, as are alſo *Sciſſars*, *Pinchers*, *Snuffers*, &c. This *Leaver* has the Power at one End, the Weight at the other, and *Fulcrum* in the Middle.

Fig. 13. Is a *Leaver* of the ſecond Kind, as are alſo the *Oars* and *Rudders* of a *Boat*, cutting *Knives* fixed at one End, and *Doors* moving on *Hinges*.

Hinges. These *Leavers* have the Weight in the Middle, the Power at one End, and the *Fulcrum* at the other.

Fig. 14. Is a *Leaver* of the third Kind, as are also *Ladders* taken up by the Middle to be reared against a *Wall*. This *Leaver* has the Power in the Middle, the Weight at one End, and the *Fulcrum* at the other.

Fig. 15. Is a bended *Leaver* of the fourth Kind; but it may as well be reckoned a *Leaver* of the first Kind, because its *Fulcrum* is between the Power and the Weight; when you draw a *Nail* with an *Hammer* it becomes a bended *Leaver*.

Fig. 12 *and* 15.) In a *Leaver* of the first or fourth Kind, the Weight and the Power may be equal, as it must happen when A C is equal to B C. The Power may be greater than the Weight, as when B C is greater than A C, or the Weight greater than the Power, as when A C is greater than B C.

Fig. 13.) In a *Leaver* of the second Kind, the Weight must be always greater than the Power, because its Distance from the *Fulcrum* will be always less than the Power's Distance; for wherever the Weight D is applied; A C will be a Part of B C,

and

and therefore muſt always be leſs than its whole B C.

Fig. 14. In a *Leaver* of the third Kind, the Power muſt always be greater than the Weight, becauſe C E the Diſtance of the Power will always be leſs than A C, of which it can be but a Part.

N. B. *In all theſe Caſes an* Æquilibrium *is ſuppoſed.*

Prop. III. *Theoreme.*

A Power which puſhes or draws a *Leaver* at right Angles, has greater Effect then at oblique Angles.

DEMONSTRATION.

Fig. 16. Since the Force of a Power depends upon its Diſtance from the firſt Point, and ſince (by *Def.* 9.) the Diſtance of the Power is a Line drawn perpendicular to the Line of Direction; it is plain by Conſtruction, that C B the Diſtance of the Power applied at right Angles, is greater than C F the Diſtance of it applied at obtuſe, or C K the Diſtance of it applied at acute Angles, and drawing towards I.

For ſince (by 15 *Def*: 1. *El*: *Eucl*:) C F = C L = C K, and C L being Part of C B, (the Diſtance of the Power drawing at G, and applied at right Angles) is leſs than C B (by *Ax*. 9. 1 *El.*) Likewiſe C F and C K muſt be leſs than C B: Therefore a Power applied at right Angles, has a greater Effect than if applied at oblique Angles K E G.

N. B. *C F is the Diſtance of the Power E, applied at B, and drawing at obtuſe Angles, as the Angle C B E and C K is the Diſtance of a Power ſtill applied at B, and drawing in the Line I K at the acute Angle C B I.*

Prop. IV. *Theoreme.*

Plate 2*d*. *Fig*. 1.) If a Power, whoſe Line of Direction is perpendicular to a *Leaver* parallel to the Horizon bears up, by means of that *Leaver*, a Weight whoſe Center of Gravity is above the *Leaver*, it muſt be greater to bear it up, when the *Leaver* is horizontal, than when it is inclined, and the Weight raiſed; and greater yet when the Weight is lower, the Line of Direction of the Power always remaining perpendicular to the Horizon;

rizon. The Reaſon of this is, becauſe the Body does not hang freely from the *Leaver*, to which it is fixed; for if it did, the Diſtance of the Weight would decreaſe in the ſame proportion as the Diſtance of the Power does, when the *Leaver* is moved out of its horizontal Poſition: That is, when the *Leaver* I B (where I C is the Diſtance of the Weight, and C B the Diſtance of the Power) is moved into the Poſition O D, and the Diſtance of the Power at D becomes C N (by *Def.* 9.) the Diſtance of the Weight would become C *h*, if the Weight was to hang freely from E; but ſince the Body E O M is fixed to the *Leaver*, it endeavours to deſcend in the Line of Direction O L, drawn perpendicularly downwards from the Center of Gravity O, which cauſes the Diſtance of the Weight to be only L C inſtead of h C; and therefore the Body's Gravity decreaſing in greater Proportion than the Force of the Power, (which is a Weight that hangs freely) the Body O requires a leſſer Power to bear it up when it is fixed upon an inclined *Leaver* above the Horizon, than when that *Leaver* is parallel to the Horizon. Likewiſe in the *Leaver* A K, if the Body O, or the Weight was to hang freely from F, its Diſtance would be

t C decreased in the same Proportion as C Q the Distance of the Power; but since by reason of the Body's being fixed above the *Leaver*, the Line of Direction produced is K O g and its Distance; g C its Gravity must be greater, when by the Inclination of the *Leaver* it is below the Horizon Q.

Plate 2d. Fig. 2d.) The *inverse Prop.* is true of the Center of Gravity of the Body below the *Leaver*.

Since the Demonstration of this *Theor.* is the same as the other, a Sight of the Figure is sufficient; where you may observe that in the *Leaver* A E the Distance of the Weight is M C, whereas it would be n C if the Body should hang freely; and in the *Leaver* D G the Distance of the Weight is C n, whereas it would be C M if the Body should freely hang.

If two carry a Weight upon, or hanging from the Middle of a *Leaver*, he carries most who is nearest to the the Weight. *(Vide 3d and 4th Fig.)*

Of the *Leaver* or *Balance*, is meant what *Archimedes* said of his lifting up the whole Earth if he had a Place to fix his Instrument; and it was by these Powers that he is said to have lifted the *Roman* Ships.

Of

Of the Pulley.

Prop. I. *Theoreme.*

Plate 2. *Fig.* 7.) WHEN a Power by ſeveral *Pullies* draws up a Weight, the upper *Pullies* are *Leavers* of the firſt Kind, and the lower *Pullies Leavers* of the ſecond Kind; for in C E and B H, the Powers are applied at E and H, the Weight at C and B, and the *Fulcra* are in the Middle O; but in I K and F G, the Powers are applied at I F, the Weights at O and K G are the *Fulcra*.

Prop. II. *Theoreme.*

Plate 2. *Fig.* 5.) An upper *Pulley* adds no Force to the Power, becauſe it is a *Leaver* of the firſt Kind, with its *Fulcrum* juſt in the Middle; and in ſuch a Caſe the Velocity of the Weight is not diminiſhed, and conſequently that of the Power not increaſed.

Prop.

Prop. III. *Theoreme.*

Fig. 6.) A lower *Pulley* takes off half the Velocity of the Weight, and ſo doubles the Force of the Power; becauſe whilſt 10 moves one Foot, 5 moves two Foot.

Prop. IV. *Theoreme.*

Fig. 7.) As one is to the Number of the Parts of the Rope applied to the lower *Pullies*, ſo is the Power to the Weight. *Ex. Gr.* If the Hand can raiſe but ten Pound without an *Engine*, it will by the Help of the *Pullies*, [*Fig.* 7.] be able to raiſe forty Pound; or one Pound hanging at A will keep in *Æquilibrio* four Pound hanging at the loweſt O, or in the Place of the Body D.

Prop. V.

What a Power by a *Pulley* gets in Strength, it loſes in Swiftneſs, as it does by all other *Engines*.

Of the Axle in the Wheel.

Prop. I. *Theoreme.*

Fig. 8. AS the *Radius* of the *Axis* to the *Radius* of the *Wheel*; ſo the Power to the Weight: That is, as C D to A B, ſo is the Power applied at A to the Weight; or rather, as the Circumference of the *Wheel* = Velocity of the Power = is to the Circumference of the *Axis* = Velocity of the Weight =, ſo is the Weight to the Power.

COROLL.

Plate 2. *Fig.* 10.) This is obſerved in *Watches*, where the *Radius* of the *Wheel* in the *Fuze* increaſes, as the Force of the Spring is weakned; that the *Axis* of the *Fuze* may be always turned round with the ſame Force. When the Spring is Strongeſt it draws at A when weakeſt at B.

Prop. II. *Theoreme.*

An *Axis* in *Peritrochio* is a *Leaver* of the firſt Kind; A B the *Radius* of the *Wheel* being the Diſtance

ſtance of the Power ; and C D the *Radius* of the *Axis* being the Diſtance of the Weight. *Fig.* 8.

By the Multiplication of *Wheels*, an *Hair* may draw up an *Oak* by the Roots.

To this Power are reducible, *Whimbles*, *Augors*, *Windlaſſes*, *Trepans*, &c.

Of the Wedge.

Fig. 11. A *Wedge* is the moſt Simple of *Mechanical Engines*, and is a ſolid *Triangle* ; uſually of *Iron*, to ſlide againſt the Parts of the Body it cleaves.

To underſtand the Power of the *Wedge*, one of the two flat Sides which incline to one another, is to be look'd upon as an inclined Plane, and the other as an horizontal Plane ; and we muſt conceive that by the help of this inclined Plane, a Power ſhall raiſe a Weight, which without this *Engine* it could not ſo much as bear up.

Fig. 15.) Let the Triangle D B C, Rectangular at B, repreſent a *Wedge*, D the Point or Edge of it, B C the Head; and to be more plainly underſtood,

ſtood, let D B the Length of the *Wedge* be twice its Height B C, and the *Baſis* B D perfectly Smooth, ſo that being applied to the horizontal Superficies A B, which alſo I ſuppoſe perfectly Smooth, the *Wedge* D B C may ſlide upon that horizontal Plane A B, without any Difficulty. Then again, let us ſuppoſe that the Weight E be hindred from going to A by the Plane H I K perpendicular to the Horizon, which yet does not hinder the *Wedge* from ſliding along the horizontal Plane A B, when it ſhall be drawn or puſhed from B towards E, by a Power whoſe Line of Direction is parallel to the Horizon. If then the Power puſhes the *Wedge* D B C regularly from B towards A, in cauſing it to ſlide upon the horizontal Plane A B, it will cauſe the Weight E to riſe up by ſo regular a Motion, that its Center of Gravity E will never go out of the Line E F perpendicular to the Horizon; ſo that when the Point B ſhall come to D, the Point C to F, and the Point D to G, (that is, when the *Wedge* D B C ſhall be in the Poſition G D F) the Weight E by the Reſiſtance of the Plane A I K ſhall have been forced to riſe by the inclined Plane C D, or F G, which will have puſhed it

upwards towards F; ſo that it will have riſen the whole Length of the Line D F, when the Power ſhall have moved the Length of the Line B D or G D, which is twice D F by the *Suppoſition.*

Since then in this *Suppoſition* the Power has double the Velocity of the Weight, it ought to have double the Force of the Weight; therefore it needs not be more than half the relative Weight of that *Pondus* upon the inclined Plane C D to be able to bear it there; according to that general Law of *Mechanicks* which we have taken Notice of in the foregoing *Engines (viz.)* that the Power increaſes proportionally as its Velocity increaſes: Whence we may eaſily conclude, that when a Power whoſe Line of Direction is parallel to the Horizon, ſuſtains a Weight by the Means of a *Wedge,* whoſe *Baſis* is alſo parallel to the Horizon, that Power is to the Weight it bears up : : as the Height of the *Wedge* to its Baſe.

COROLL.

Hence the ſharper the *Wedge* is, the more eaſily it will enter, becauſe G the Velocity of the Power [*Fig.* 12. *Plate* 2*d.*] will be greater in proportion to F, that of the Weight; and when this

this *Wedge* shall be used to cleave a Body, as A B C D, the more the Planes E F G O which make up this *Wedge*, are inclined to one another, the more easily will the Parts E G slip along the *Wedge*.

N. B. *E F O must be taken for an inclined, and G O for an horizontal Plane, and the Resistance that the Body A B C D makes in its upper Part when it is disunited from its lower, may pass for a Weight, whose Line of Direction is perpendicular to its lower horizontal Part C D.*

This which is true in the Theory, would hold in the Practice if the Plane of the Wedge, and that Plane whereon it slides were perfectly Smooth, and the Weight truly Spherical; but since there cannot be of such a Mathematical Exactness, the Practice won't hold; therefore Percussion *is applied, which is the only effectual Means, because the Parts of the Wedge will stick less when the whole is put into a Tremulous Motion.*

SCHOLIUM.

The Reason why a small *Hammer* with a violent Blow, will not have so much Effect as a

ſmall Blow with a *Sledge*, is, that a *Sledge* with a ſmall Force added to its Gravity, will have more Motion downwards, than a little *Hammer* with a ſwift Blow, becauſe the Motion is in a *ratio* made up of the *Pondus* of the Velocities.

Plate 2. *Fig.* 13.] The *Wedge* may be reducible to the *Leaver*: Thus C D A is as two *Leavers* of the firſt Kind, whoſe fixed Points are at B B, or rather as in *Fig.* 14. it repreſents two *Leavers* of the ſecond Kind, whoſe *Fulcra* are in the common Point A.

The Weights to be moved at C, and the Powers applied at B.

To this Power are reducible *Nails*, *Bodkins*, *Hatchets*, *Knives*, *Saws*, *Files*, &c. being *Wedges* faſtened to *Leavers* of the ſecond Kind.

Of the SCREW.

Plate 2. *Fig.* 17. THE *Screw* is nothing but a *Wedge* continued round a *Cylinder* in a Spherical Manner; the *Male-Screw* A B is an outſide, and the *Female-Screw* C D an inſide *Screw*.

To

To ſhew better how the *Screw* works, ſuppoſe the Weight E to move upon the ſolid Triangle, D C B from E to C, it will be the ſame thing as if the ſolid Triangle had moved under it, and forced it up to F, where it muſt go, becauſe the *vertical* Plane H I K L hinders it from riſing in any other Line beſides E F. Now, becauſe the Power has moved the whole Length of the Line C D, and the Weight only that of the Line E F, the Power muſt be the Weight : : as the Length of the Line E F, which is the Velocity of the Weight, is to the Length of the Line D C, which is the Velocity of the Power.

Fig. 16.] To eſtimate therefore the Force of the *Screw*, we muſt look upon the Height of the *Cylinder* H I P Q as the Velocity of the Weight, and the Thread H K L M N O P (if its *Helexes* were unwound and laid at full Length) as the Velocities of the Power: Therefore by the Force of a *Screw*, the Gravity of a Weight, or any other Preſſure will be leſſened as much as the Spiral Line H K L M N O P, is greater than H P or I Q, the perpendicular Height of the *Screw*.

CO-

COROLL.

Hence the closer the Thread of the *Screw*, the greater will be its Force, because its Thread will be longer in proportion to its Height, and it will move the slower.

SCHOLIUM.

If long *Leavers* be added to the *Screw*, its Force will be still increased after the manner that was shewed in the Explication of the *Leaver*.

The Advantage of this *Mechanical Faculty* is, that whereas other *Mechanical Engines* cease to act, and the Weight returns when the Power does not continue to act; this sustains the Weight, and retains all the Force that was communicated to it, when the first Mover ceases to act, because the Weight pressing the *Cylinder* along the *Axis*, pushes the Threads of the *Male-Screw* against those of the *Female-Screw*; whereas an *Helical* Motion is requir'd to unscrew so much as is screwed up of the *Instrument*. Now in other *Engines*, a *Pulley*, for Example, or *Leaver*, the Weight will return as soon as the Hand ceases to pull

pull the Rope, or press upon the End of the *Leaver*.

Plate 2. *Fig*. 9.] But then there is this Disadvantage, that a *Screw* is screwed up as far as it can go in a little time, which Inconveniency may yet be remedied in compound *Engines*, if you make it a perpetual *Screw* and apply it to a *Wheel*, as in the *9th Figure*, where the perpetual *Screw* C D E fixed to the *Cylinder* A B takes the Teeth of the *Wheel* F, and turns it continually the same way, till it has by means of its *Axis* drawn up the Weight G, tho' ever so distant at first.

That this Power is reducible to a *Leaver*, appears from its being a *Wedge*, which we have shewed to be made up of two *Leavers* of the first or second Kind.

Of the LAWS of NATURE.

THE *First* LAW *of* NATURE, is, that all Bodies endeavour to preserve themselves in the same State, either of Motion or Rest. So that if the Body be at Rest, it never

comes

comes of its own accord to Motion, but muſt have ſomething to move it; and if it is once in Motion, it endeavours to perſiſt in that Motion, always according to the ſame Direction in the ſame ſtrait Line, nor can it be ſtopt but by a Force equal to the Force of its Motion. This is plain, for Bodies being of an unactive Maſs of Matter can acquire no Change or Mutation of their own State; and a Body can no more change its Motion, and come to Reſt, than it can change it ſelf from one Figure to another; after the ſame manner it can never change its Direction, but will always continue to go forwards in the ſame ſtrait Line. But whatever Change is made in a Body, muſt be by ſome extrinſical Agent; and if a Body ever changes its Direction, there muſt be ſome external Agent to make that Change of Direction, and if it were left to it ſelf, it would always move uniformly forward in the ſame ſtrait Line: If a Body move in any *Medium*, it muſt neceſſarily thruſt away Parts of the *Medium* that are in its way; and therefore ſince whatever Motion it communicates to them, it muſt loſe it ſelf. A Body that moves in the Air muſt continually loſe of its Motion; whereas if there was no Gravity, nor

nor any Air, a Stone once thrown up would go on in *infinitum*, without losing its Motion. The Air then is the only Cause why Bodies lose of their Motions when thrown up, and Gravity is the only Cause which brings them to the Earth.

In the Heavens where the *Æther* is exceeding thin, and next degree to nothing, the *Planets* preserve their Motions without the least sensible Diminution: From hence we know the way how Motion is communicated to Bodies; for when a Man holds a Stone in his Hand, the Stone participates of the Motion of his Hand, because being in it, is moved with the same Velocity as the Hand is: Now by this *Law of Nature*, a Body once put in Motion, will always endeavour to go forward according to the same Direction. And therefore, when the Man draws back his Hand without the Stone it having once had a Motion forward, will always endeavour to continue in it. Because all Bodies affect to move in a strait Line, there must necessarily be some Force to make them move in a crooked. This Force may be either a *String*, by which they are tied to the *Center* of their Motion, or by some other *Centripetal* Force, such as *Gra-*

ty, which continually presses them towards the *Center*.

Plate 3. *Fig*. 3.] Suppose a Body put in Motion at A, it will endeavour to move in the same strait Line A B; but the Force of *Gravity* continually pressing it towards the *Center*, that is, from B downwards, or in a Line perpendicular to the Earth, it will move in the *Diagonal* of the *Parallelogram* C if you fill it up.

Plate 3*d*. *Fig*. 6.] When the *Bomb* is by the Force of the *Powder* thrown out of the *Mortar*, it endeavours by the *First Law of Nature* to go on in the right Line *c e*; but *Gravity* acting upon it in the Direction *e b*, makes it move in the Line *c b*, *Diagonal* of the *Parallelogram*, contained under the Lines *c e e b*; that is (supposing two other Lines to be drawn = and ‖ to the said Lines *c e e b*) by a Motion compounded of the Force pushing towards *a* from *c*, and that which pushes towards *b* from *e*.

Then the *Bomb* would by the *First Law of Nature* continue to go on towards *d* in the Line *d g*, being the aforesaid *Diagonal* produced; but *Gravity* acting upon it in the Direction *g f*, makes it by a compounded Motion go on in the *Dia-*

Diagonal b f of the new *Parallelogram* contained under *a g g f*, and ſo on till it comes to the Point *h*. Now ſince the firſt *Impetus* and *Gravity* does not act alternately, but at the ſame time all the while the *Bomb* moves, we muſt ſuppoſe the ſaid *Diagonals* (in which the Body moves) to be infinitely ſmall ; and then all of them together will make up the *Curve c b f h*, called a *Parabolick* Line, in which all *Projectiles* move.

The ſwifter a Body moves in a Circle, the ſtronger is its Endeavour to move in a ſtrait Line, and the more the Thread will be ſtretched by which it is kept in; the Force by which it ſtretches the Thread is called *Centrifugal* Force (as is eaſily ſeen in *Slings*) and the Force of the Thread which detains it, muſt be juſt equal to this *Centrifugal* Force ; but if *Gravity* or any other *Centripetal* Force detains the Body in its *Orbit*, the *Centripetal* Force muſt be juſt equal to the *Centrifugal*, that the Body may be kept in the ſame Circle.

If a Body lye upon a Table, and if the Table be moved, at firſt the Body will not participate of the Motion of the Table, but will ſeem to go the contrary way; as is plain from a Veſ-

ſel of Water ſet upon a Table; but after that Motion is once communicated, if you ſtop the Table ſuddenly, the Body lying on it will continue its Motion. If a round Table parallel to the Horizon, be turned round an *Axis*, and a *Bullet* by the Help of a Thread made faſt to the *Center*, [*Plate 3d. Fig. 5.*] tho' the Thread be ſlack at firſt, yet the Table being turned round, the *Bullet* at C will recede from the *Center* and ſtretch the Thread as at D; if the Table be ſtopt on a ſudden, yet the *Bullet* will for ſome time continue its Motion; if the *Bullet* be not put upon the Table, but hang down by the Thread, as in the Poſture A B, after the Table is turned round the Thread will not keep its perpendicular Poſition, but will ſettle it ſelf in the Poſition A *b*, the *Centrifugal* Force acting againſt the Force of *Gravity*, and making the Body recede as far as it can from the Center of Motion.

If a *Glaſs Tube* be laid or faſtned to a Table, in which near the *Center* be put a ſmall *Bullet*, when the Table is turned round we may obſerve the *Bullet* to recede from the *Center* towards the *Circumference*, and accelerate its Motion.

Beſides

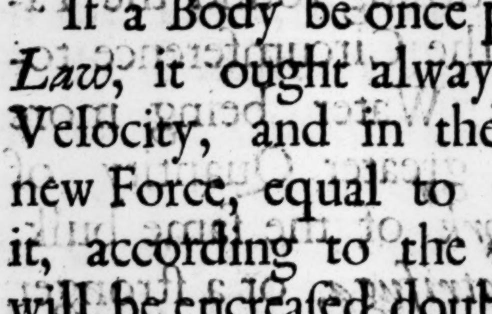
Besides this, it will go against the common *Law of Gravity*, and move upwards if the *Tube* be set slanting upwards on the Table, being first fixed to a Piece of Wood, represented in *Fig*. 4. *Plate* 3. and it will stay at the upper End of the *Tube* beyond, as long as the Table is continued in its swift Motion; but when that ceases it is pressed down again by its own *Gravity* to G.

The same is observed when we put *Globules* of *Mercury* or *Water* in the *Tube*. If we fill the *Tube* with Water, and put a piece of *Cork* in the End of it, which is next to the Circumference, we may observe, that after turning round the Table, the *Cork* will go from the Circumference towards the Center; for the Water being more *Dense*, or consisting of a greater Quantity of Matter, than the Piece of *Cork* of the same bulk, it will have a greater *vis Centrifuga*, or a stronger *Conatus recedendi a Centro* than the *Cork* has; and consequently the *Cork* which has much less Force, will be pushed by the Water which has a greater Force towards the Center.

The Second LAW *of* NATURE, is, that the Motion produced, or the *Mutation* of Motion, is always

always proportional to the Motion imprest, which generates the Motion. A double Force will produce a double Quantity or *Momentum* of Motion; and a triple Force, a triple, &c. and this Motion will always be according to the Direction of the Force which impresses it; and if the Body was moved before this new Motion arising from this new Force, it will either increase its Motion, if it acts according to the same Direction, or diminish it, if it acts in a contrary Direction; or if it acts obliquely, it alters the Direction, and turns the Body moved another way.

If a Body be once put in Motion by the *First Law*, it ought always to go on with the same Velocity, and in the same Direction; but if a new Force, equal to the former, act again upon it, according to the same Direction its Motion will be encreased doubly. If, again, the same Force acts, its Motion will be triple of the first, &c. Thus if A was put in Motion towards B, having once acquired an *Impetus* that way, it would always continue in it; but if we should suppose that when the Body comes to C, that the same



Force acted again upon it, it would produce a Motion equal to the former; and both of them put together will be double of the first. Again, when the Body comes to D, if the same Force should act again upon it, there would arise a new Quantity of Motion equal to either of the former, and the whole being put together will be triple of the first Motion. If, again, when the Body comes to E, the same Force acted upon it, it would again produce more Motion, which would be equal to the first; and so the whole Motion arising from all these Actions put together, would be *Quadruple* with the first. If this Force thus acting imprinted equal Degrees of Motion at equal Intervals of Time, the Motion produced, and consequently the Velocity will be as the Times when a heavy Body descends; *Gravity* acting upon it at first, gives it a Motion downwards: Now if the Body should cease for ever after to be heavy, yet the Body will go on in the same Direction, and with the same Velocity by the *First Law*; but then in the second Instance of Time, the Body is heavy, and *Gravity* continues to act, it will again produce a Moti- equal to the former.

Just

Just ſo if the Body ſhould for ever ceaſe to be heavy, yet it would ſtill continue its Courſe with the two acquired Degrees of Velocity; but then *Gravity* acts the third Inſtant of Time, after the ſame manner it did at firſt, and makes a Motion equal to the firſt Degree, and therefore the Sum of the whole will be triple with the firſt. After the ſame manner the Motion the fourth time will be *Quadruple* of what it was the firſt Inſtant, and ſo the Motions will always increaſe the Times. This is the Reaſon why we find Bodies in their deſcending accelerate their Motions. When Bodies fall, the Spaces through which they deſcend, are the Squares of the Time they take to fall in, always counting from the beginning thus.

Plate 3d. Fig. 7 *and* 8.] If in the firſt Minute of Time a Body falls through a certain Space, at the End of the ſecond Minute it will have deſcended four Times in that Space; in the End of the third Minute it will have deſcended nine Times that Space which it did go through in the End of the firſt. So if the Times be taken in *Arithmetical* Progreſſion of 1, 2, 3, 4, 5, 6, then the Spaces through which the Bodies will have deſcen-

deſcended at the End of theſe Times, will be as 1, 4, 9, 16, 25, *&c.* If it be asked how far the Body moves in the ſecond Minute? It will have moved juſt three Spaces; for it had moved thro' one in the firſt, and ſo likewiſe in the third Minute 'twill have moved thro' five; for at the End of the ſecond Minute it had moved thro' four; take four from nine, and there remains five.

The two rectangular Triangles of *Fig.* 7. made up of other rectangular Triangles, repreſent the Spaces gone thro' in a determinate Time, each ſingle Triangle denoting one Space: As for Example, in the upper *Figure* marked 7, if we ſuppoſe a falling Body to ſet out at the rate of one Mile in one Minute; let the N° 1. and the Perpendicular of the little Triangle at top expreſs the firſt Time or Minute, and the ſame N° 1. and the Baſe of the little Triangle expreſs the Velocity, which always is at the Times; and let the whole Triangle expreſs one Mile that the Body fell the firſt Minute; then if you conſider that the Body having fallen four Times, the Line expreſſing the Time muſt be the Perpendicular of the great Triangle, which ⊥ is four times greater than that of

the little upper Triangle: Likewiſe the Line expreſſing the Velocity muſt be in the Baſe of the great Triangle, which Baſe is four Times greater than the Baſe of the little Triangle; and the whole Triangle will be the Sum of the Spaces or Miles gone thro' in four Minutes, which will appear by dividing it into little Triangles equal to the firſt. A Sight of the Figure will eaſily teach how to know the Miles that the Body has fallen thro' in any Number of Minutes or Times.

If a Body [*Fig.* 10. *Plate* 3..] as A lies upon an inclined Plane, it endeavours to deſcend Perpendicular, but the Plane hindring it, with part of its Weight it will preſs upon the Plane, and with the reſt it will deſcend as faſt as it can along the Plane; but it will not accelerate its Motion ſo faſt, as if it did all along deſcend Perpendicularly; thus in falling from B to C, it takes longer time than if it had gone directly from B to D in the ⊥, ſo that at the Point C it will have as much Velocity in falling from B to C, as it will have at D, in falling from B to D. The leſs the Plane is inclined to the Horizon, or the nearer it comes to the ⊥, the faſter it will accelerate its Motion.

Fig.

Fig. 11.] Thus it will fall ſooner from B to G, than from B to C, and ſooner from B to E, than from B to F; but in falling from the ſame Point B to the Points D E F G C, the Degrees of Velocity acquired are all equal, tho' they be acquired in unequal Times. *V. G.* Suppoſe B C three Times longer than B D, the Body will go from B to D in the third part of the Time that it goes in the Plane of B C from B to C; but the Velocity acquired in the deſcending from B to D, is the ſame that is acquired in the deſcending from B to C, and therefore it will accelerate its Motion in the Line B D three Times faſter than in the Line B C.

If a Body in falling from B to D acquire any Degree of Velocity, and with that Velocity be turned upwards, it will juſt aſcend to the ſame Height from whence it came, and *Gravity* acting upon it will leſſen continually its Velocity, in the ſame proportion it increaſed before in deſcending, and after it has come to the Point B it will immediately deſcend again: After the ſame manner, if having fallen along B D [*Plate* 3. *Fig.* 12.] it be turned up on the inclining Plane D C with that Velocity which it acquired in de-

ſcending, it will juſt go to the ſame Height from whence it fell.

Fig. 14.] If a Body B hanging by the String A B down towards E, be moved from B to D, and from thence let fall, it will continually accelerate its Motion till it comes to the Point B or E ; and then with all its Force it will go into the Arch B C to the Point C of the ſame Height with the Point D from which it fell, and then at the Point C it will deſcend to D, and there it will have the ſame Velocity as it had before at B, with which it will aſcend to D and ſo make *Vibrations* continually. The Body ſo hung by a String is called a *Pendulum.* Suppoſe a Circle, whoſe Plane is ⊥ to the Horizon in which were drawn ſeveral ſmall *Subtenſes* B D, B E, B F from the lower-moſt Point B, [*Plate 3d. Fig. 9th.*] the Body will deſcend in the ſame Time along the Line B D, from D to B, or along the Line F B, from F to B.

The Reaſon is this, tho' the Line F B is longer than the Line B D, yet it is alſo more ⊥, or leſs inclined to the Horizon ; and conſequently the Body will accelerate its Motion faſter upon the Line B F, than upon the Line B D ; becauſe ſmall

Arches

Arches do not differ much, either in *Declivity* or Length from their *Chords*. *Bodies* will very nearly descend in the same Arches of *Circles*, that they will do in the *Chords* of those Arches; but *Bodies* descend in the same Time thro' all those *Chords*, whether they be greater or lesser; and consequently the *Vibrations* of the same *Pendulum*, whether it run out in a greater Arch, or lesser, are all performed in the same time.

Plate 3. *Fig*. 16.] Let A fall from 8, and B from 4, the Velocity with which A will be moved being so much greater than that of B, they will both meet equally at the Point C; the shorter the Strings are, the quicker are the *Vibrations*; because the String is as the half *Diameter* of the *Circle*; and so the less the String is, the lesser the *Circle* will be; and consequently the less the *Circle* is, the quicker the Body will be moved round it.

The Third LAW *of* NATURE, is, that Action and Re-action are always Equal and Contrary, *i. e.* the Actions of *Bodies* one upon another, are equal, and the Force imprest is always directed towards contrary Parts; so that the *Mutation of*

Motions

Motions, which thoſe Actions produce are equal. This *Law* will be illuſtrated by ſeveral *Examples*: Firſt, if the *Body* A moving towards C, meet with B at Reſt, whatever *Motion* the *Body* B gets by the Impulſe, ſo much preciſely will the *Body* A loſe. *V. G.* If the *Body* A have twelve Degrees of *Motion*, and after the Impulſe B have five, then A will have but ſeven remaining; and therefore there will be equal *Mutations* of *Motion* in both, and the Effect will be the ſame, as if a Force equivalent to five Degrees of *Motion* acted upon A towards C, contrary to its former *Motion*, and another equal to it acted upon B impelling it towards C; and univerſally when one *Body* hits another, the *Stroke* or *Blow* is equally received in both. and it is always proportionable to the *Motion* loſt in *Percutient Bodies*. If an *Horſe* draws a *Stone* which is tied to a String, the Force by which the *Horſe* is pulled back towards the *Stone*, is equal to the Force by which the *Stone* is drawn towards the *Horſe*; for the Rope being equally ſtretched by the ſame Power it has to contract it ſelf, will put equally the *Stone* towards the *Horſe*, and the *Horſe* to-

wards

towards the *Stone*; and therefore the Force of Attraction in the *Horſe* and in the *Stone* are both equal; but ſeeing the Strength of the *Horſe* is ſo great, and aſſiſted by the Ground on which he ſtands, that he can reſiſt the Attraction of the Rope, he will not in the leaſt yield to the Attraction of the Rope, nor be pulled out of his Place; but the ſame *Stone* which has ſo great a Force of Reſiſtance, will be drawn towards the *Horſe*. If the *Magnet* or *Load-Stone* attract *Iron*, the *Iron* will likewiſe equally attract the *Load-Stone*; this may be ſeen if you hold the *Iron* in a fixed Point, and the *Load-Stone* hang in a *Scale*, or be ſuſpended by a String. The ſame thing is true in all other Attraction.

Plate 3. *Fig*. 18.] Suppoſe two *Boats* A and B floating in the Water, and a Man in one of them. *V. G.* A, by the help of a Rope, pulls the *Boat* B towards him, and that by that Attraction not only the *Boat* B carries to A, but alſo the *Boat* will be equally drawn to B; ſo that the Quantity of Motion will be equal in both; and if the *Boats* be of the ſame bigneſs and weight, they will meet at E the Mid-way between A and B. But ſuppoſe B 10 Times greater than A, = then B will

will have 10 Times leſs Velocity than A, and the *Boats* will meet not at E but at D, ſo that D G will be 10 Times longer than F G; if B is 1000 Times greater than A, they will meet at the Point D, which will be ſuch, that G D will be 1000 Times greater than D F, and conſequently it ought to have 1000 Times leſs Velocity, ſo as to make the *Momentum* equal in both. If B be vaſtly greater than A, its Velocity will be vaſtly leſs, and altogether inſenſible. If a Man in A by the help of a *Pole*, thruſt the *Boat* B from him towards H, by that thruſting the *Boat* B forward, the *Boat* A will be thruſt backwards towards K.

So that that there will be equal Quantities of Motion in both towards contrary Parts; and therefore if B is 10 Times greater than A, B will move towards H with 10 Times leſs Velocity than A; which moves the contrary way towards K, ſo that the Quantities of Motion in both are equal. If B is immenſely bigger than A, its Velocity will be leſs than A's in the ſame proportion, and conſequently its Velocity will be altogether inſenſible in reſpect of A's, and may be reputed as none.

Fig.

Fig. 17. *Plate* 3*d.* And therefore if a Man in a *Boat* thruſt the Earth or Shore from him, the *Boat* by this thruſting will recede from the Shore; for the Shore may be conſidered as a prodigious great *Body* in reſpect of the *Boat*, and conſequently its *Velocity* will vaniſh and be equivalent to nothing. When a *Boat* is rowed with *Oars*, the Water by the Motion of the *Oars* is repulſed back to C, and therefore will re-act upon the *Oars*, and give to the *Boat*, to which they are fixed, a Motion towards D; and it is only upon this Account that the *Boat* advances forwards; for if there was no Re-action, and the Water by being thruſt back did not give the *Boat* a Motion forwards, they muſt ſtand ſtill, becauſe there would be no Cauſe for its Motion; but now ſince the Water re-acts upon the *Oars*, it communicates by its Re-action, as much Motion to the *Boat* forward, as the *Oar* did to the Water backward.

Since *Swimming* is nothing but Rowing with our Hands and Feet, we may eaſily underſtand the Reaſon why by this Motion of our Hands and Feet we advance forwards; for when the Water is thruſt backward, it by Re-action will repel the *Swimmer* forward. Likewiſe when by the Motion

of our Hands we thrust the Water down, it will by Re-action force us upwards.

And the same thing is to be applied to the *Flying* of *Birds*, which is nothing else but *Swimming* in the Air. The general *Rules* that all *Bodies* observe in their Motion, is this: The Sum of their Motions towards the same Part, (which is known by taking the Sums when the *Bodies* move the same way, and the Difference when they move contraryways) remains the same always before and after the mutual *Impulse*.

BODIES that have no *Elasticity* after their Congress, move together without any Separation towards the same Side where was most Motion; and because the Sum of their Motions is always the same before and after Percussion, if we take the Sum and divide it by the Quantity of Matter or Weight of the *Bodies*, the Quotient will give their common *Celerity* with which they will move after their Conjunction. Suppose A B equal each, for *Ex.* to a *Body* of five Pounds; and suppose B at rest, and A to move towards it with four Degrees of *Velocity*; because B has no Motion, the Sum of their Motions will be four times Five, or Twenty, which being divided by the Sum of their Weight

Weight *(viz.)* Ten, their Quotient Two will be their common *Velocity* after Conjunction: So that if one *Body* move directly upon another, equal to it which is at rest, after their Conjunction they will go together with half their former *Velocity*. If A and B were equal, and B moved according to the same Direction with A, but with less *Velocity* after their Conjunction, they will both go together with half the Sum of their *Velocities*. Suppose A's *Velocity* Eight, and B's Six after Impulse, the *Velocity* of each will be One; if B moved by a contrary Direction with less Motion than A has, then if the *Bodies* be equal they will move together with half their Difference after meeting; but universally their *Velocities* are determined by taking the Difference of their Motions, which is the Sum of their Motions towards the same Direction, and dividing it by the Sum of the *Bodies*. Suppose A to be ten Pounds and B to be six, let A's *Velocity* be Five, and B's Three, the Difference of their Motion is Thirty-two, which being divided by Sixteen the Sum of the Bodies, the Quotient Two is the common *Velocity* after meeting. If A and B moving contrary Ways, have equal Quantities of Motion, after Concourse they will both rest; for

in this the Difference of their Motions being nothing, after meeting they can have no Motion. As for Example, ſuppoſe A ten Pounds and B Eight Pounds; let A's *Velocity* be Four and B's Five, in this Caſe the Motion in each will be Forty, there being no Difference of Motions, the two equal and contrary Forces acting one upon another will deſtroy one another's Motion; and therefore *Des Cartes*'s *Law of Motion* is falſe, by which he ſaid, *There was always the ſame Quantity of Motion preſerved in the World.*

If there was no *Elaſticity*, the former *Laws* would ſerve for all *Bodies*; but by Reaſon there are few *Bodies* but what are *Elaſtick*, the Rules of common Motion are ſometimes very different from theſe already given; for by the Force of *Elaſticity* of Bodies, ſometimes they move after *Percuſſion*, and according to the ſame Direction, and ſometimes they go in contrary Direction.

That we may explain the Cauſe of *Reſilition* and *Separation* of *Bodies*, we may illuſtrate it by an Example thus. [*Plate* 3. *Fig.* 15.] Let A B repreſent a *Silken-Thread*, or *Cats-Gut*, ſtretched and ſtrongly extended upon the *Table* by the help of two *Nails*. If the *Thread* taken by the middle

Point

Point and moved out of it's Place, ſo that the Point D comes to C, and the *Thread* lye in the Poſition A C B, and then left to its ſelf, it will immediately with Force go to reſtore its ſelf to its former Poſition. Now by the continually acting of this elaſtick Force, by which it endeavours to reſtore it ſelf, it will continually increaſe its *Velocity* juſt as heavy *Bodies* do; and when it comes to the Point, it will have a Force to go on forward, equal to that by which it was forced out of its Poſition, by which Motion it will go on till it comes into the Poſition A E B, and then it will reſtore it ſelf again, and perform *Vibrations* juſt as in a *Pendulum*.

Now let us ſuppoſe a *Body*, as D [*Plate 3d. Fig.* 15.] to run from F upon the *Thread* A B, the *Thread* by this Force will be put out of its Poſition A B into the Poſition A E B, where it will quickly ſtop the Motion of the *Body* D: Now the Motion of the *Body* D being deſtroyed, the *Thread* by its elaſtick Force endeavouring to reſtore it ſelf will return to its former Poſition, with the ſame Force by which it was put out of it, and will bring back the *Body* D again with it; and when it comes to the Poſition A D B, it will have

the

the ſame Force to go forwards towards F, as it had when it was put out of its Poſition firſt. But when it was put out of its Poſition firſt, it had all the Force of the *Body* D impreſſed on it; for all that Force was ſpent in bending the *Thread*: Therefore it will reſtore it ſelf with all that Force, and conſequently drive the *Body* D backwards by the ſame with which it came upon it. The *Body* D having then once got an Impulſe backwards, equal to what it had at firſt forwards, will by the *Firſt Law of Nature* always continue in that Motion, and therefore will be reflected with the ſame *Velocity* it had at firſt forward; if the *Thread* does not reſtore it ſelf with the ſame Force with which it was bended, the *Body* will not be reflected with the *Velocity* equal to what it had at firſt. [*Plate* 3. *Fig*. 13.] If the *Body* runs ſloping upon the *Thread*, the Reflection will be oblique, ſo that the incident Angle B be equal to the reflected Angle C. If inſtead of the *Thread* there was placed an *Elaſtick Body*, and ſuppoſe its Surface bended in by the Force of the Stroke from the Poſition at D B, into the Poſition A C B, as ſoon as ever the Force of the Stroke ceaſes, the Surface A C D by the Force of *Elaſticity* will be reſtored into its former Poſi-

tion;

tion; and by all the Force by which it reſtores it ſelf, it will act upon the *Body* F and make it move back again. Now if the Body be a perfect *Elaſtick Body*, it will reſtore it ſelf with the ſame Force with which it was compreſſed, and therefore it will make the *Body* F recede from it with the ſame *Velocity* with which at firſt it advanced towards it.

Now that all *Reflecting Bodies*, as *Glaſs*, *Ivory*, *Marble*, &c. are *Elaſtick*, may be eaſily concluded from the Sound and Tingling which they give when they are ſtruck; juſt as in a *Silken* or *Lute-String*, when it is ſtretched and ſtruck, they produce an *Undulation* in the Air, cauſed by frequent *Vibrations*, after the ſame manner, but not ſo laſting; but it may be more eaſily proved from the Concourſe of *Glaſs* or *Marble Spheres*: For if you tinge one with any Colour, and let the other fall upon it, the *Percutient Body* will have a greater Portion of its Surface tinged, than that in which it touches; and therefore by the Stroke it muſt be ſomewhat flatned, tho' afterwards it reſtores it ſelf again. *Bodies* that are perfectly *Elaſtick* recede from one another after Impulſe with the ſame Velocity as before they ſtruck, or they approached one another; or which is the ſame thing,

their

their relative Velocity before and after their mutual *Percussion* abides the ſame. The Reaſon is this: *Bodies* recede from each other only by their Elaſtick Force, by which they reſtore themſelves to their firſt Figure; but that Force is equal to the Force of the Stroke by which the Figures were changed, and the Stroke is always in the Proportion of the Velocity by which they approached one another: And therefore the ſame Force will make them recede from each other with the ſame Force as they before came to each other. If the *Bodies* move towards contrary Directions, the Force of their Stroke is as their relative Velocity, which is equal to the Sum of both their Velocities; but if they go on in the ſame Direction, the Force of the Stroke which is ſtill as the relative Velocity, will be likewiſe as the Difference of their abſolute Velocities; for the relative Velocities are always as the Difference or Sum of their real Velocities, according as Bodies move in contrary or the ſame Directions.

From this Property of perfect *Elaſtick Bodies*, and the univerſal *Law of Motion*, that the Sum of their Motions towards the ſame Direction always remain the ſame, 'tis eaſy to determine the

Velo-

Velocity of each of the *Elaſtick Bodies* after *Percuſſion.*

The Rules which they obſerve, are theſe following.

1. *If a perfect Elaſtick Body comes upon another equal to it, and at reſt, after Percuſſion, the Percutient will ſtand ſtill, and the other will go forward with all the Velocity of the Percutient.*

2. *If two equal Elaſtick Bodies move according to the ſame Direction, after Concourſe they will change their Velocities one with another, and the Antecedent will have the Velocity of the Conſequent, and the Conſequent of the Antecedent.*

3. *If two equal Bodies move contrary after meeting, they will both reflect and change their Velocities one with another.*

4. *If a little Elaſtick Body comes upon a greater which is at reſt, the inpingent Body will be reflected, and the other will go forward with a Motion equal to both the Motion of the Inpingent forwards before the Impulſe, and its Motion backward after.*

5. *If the greater Body comes upon the leſſer, they will both move after the Stroke in the ſame Direction.*

Thoſe that underſtand *Algebra*, may eaſily Calculate the Velocity of all ſorts of *Elaſtick Bodies* after their *Mutual Congreſs*.

HYDROSTATICKS.

DEFINITIONS.

1. A Fluid *is a Body, whoſe Parts yield to any Force impreſſed, and by yielding are eaſily put in Motion.*

2. *A* Solid *is a Body, whoſe Parts are ſo connected, as not to be divided withuot a determinate Force.*

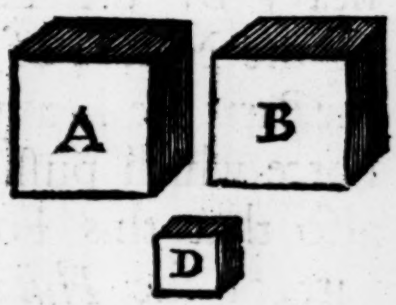
By Solidity, *we don't mean that Property of Bodies, whereby they reſiſt Penetration; but the Coherence of the Parts, by which they endeavour not to be ſeparated. Monſr.* Ozanam'*s Definition of a* Fluid *and a* Liquid *are theſe. A* Fluid *is a Body which is eaſily paſſed through, and whoſe ſeparated Parts join again immediately; as Air, Flame, Water, Oil,* ☿, *and other Liquors. A* Liquid *is a* Fluid, *which being in a ſufficient Quantity, flows continually*

continually and ſpreads it ſelf below the Air, till its upper Surface is Level, or in a horizontal Poſition.

3. Gravity *is that Force which puſhes Bodies downwards.*

4. *One Body is ſaid to be Intenſely or Specifically heavier than another, when it has more Weight and the ſame Bulk, or as much Weight and a leſs Bulk.*

Let A be an Inch of Wood, and B an Inch of Lead; if B weighs Four Ounces and A One Ounce, B will have Four Times more Specifick Gravity than A.



Let A be One Ounce of Wood and D One Ounce of Lead, if A be four Times greater than D, then D will have four Times the Specifick Gravity of A; for there is a reciprocal Proportion between the Bulk and Specifick Gravity of æquiponderous Bodies.

Prop. I.

Both the Superior and Inferior Parts of any heavy Fluid *are heavy, and the Superior preſs the Inferior by their* Gravity.

Plate 3. *Fig.* 19. LET a *Fluid* be put in the Veſſel A B C D, I ſay all its Parts are heavy, and that the Superior Parts A E F D preſs the Inferior; for ſince the whole *Fluid* is heavy by the Hypotheſis, and the Parts partake of the Nature of the whole, it appears that all the Parts are heavy; wherefore ſince Gravity is that Force which puſhes Bodies downwards, it appears alſo that this Force is exerciſed on the inferior Parts of the *Fluid*, which are therefore preſſed by the Superior.

COROLL.

From hence it follows, that the Preſſure on any Part of a *Fluid* is always according to the Height of the incumbent *Fluid*; for the Superficies E F is preſſed by A E F D, and the Superficies G H by A G H D, whoſe Weights or Preſſures are as A G.

E X-

EXPERIMENT.

Take a *Glaſs* Bubble, and having by Heat expelled ſome of the Air out of it, immediately Seal it *Hermetically*: When it is cool tye it to a Balance, and add ſo much Weight to it as will make it ſink; then put Weights in the other Scale to keep it from ſinking; then break off a Piece of the long Neck of the Bubble, within the Water, ſo that the Water may run in, and you will find that the Weight in the other Scale will not keep the Balance even; whereas if the Water within the Bubble did not weigh, the whole would ſtill be kept in *Æquilibrio*, becauſe according to that *Suppoſition*, there is no Addition of Matter that weighs.

Hence it is plain, that *Water* weighs in *Water*.

This *Experiment* refers to *Cor. Prop.* I.

On this Principle are founded all *Water-works* and *Fountains*; according to the Height of their *Reſervatories*, ſo high will the Water riſe. *V. G.* If the *Reſervatory* be Twenty Foot, the ſpouted Water will riſe Twenty Foot, allowing for the Reſiſtance of Air.

Plate

Plate 3d. Fig. 25.] If you tap a Barrel full of Water at ſeveral Places, the higheſt will ſpout out the leaſt Way, becauſe its Height from the Surface is the leaſt, and conſequently the Preſſure is the leaſt; that which is loweſt will ſpout fartheſt, becauſe farther from the Surface, and therefore the greater Preſſure will be upon it. But this muſt be underſtood if the Barrel be a ſufficient Height above the Plane on which it ſpouts, as in the *Fig.* 25. *Plate 3d.* for if the Barrel ſhould lye upon an horizontal Plane, the Liquor which comes out at the Middle of the Veſſel would ſpout fartheſt; becauſe, tho' the Liquor comes out at Bottom with the greateſt Velocity, the Plane would intercept it at a leſs Diſtance from the Barrel, than if the Barrel was higher. In ſuch a Caſe the Liquor ſpouting from an Hole, as near the Level of the Surface of the Liquor in the Barrel, as the Diſtance of the loweſt Hole from the Level of the Plane on which it is to ſpout, will fall on the Plane in the ſame Place as the Liquor that comes out at the loweſt Hole.

Plate 3d. Fig. 26.] If the Spout of a Barrel be turned upwards, the Water will riſe as high out

of

of it, up to the Height of the Water in the Barrel, *viz.* to A; and as the Water ſinks ſo will the ſpouted Water without ſink too.

Prop. II.

In any *Fluid* [*Fig.* 19. *Plate 3d.*] as A B C D, not only the Parts are preſſed downwards, but there is alſo a lateral Preſſure, and a Preſſure from all Parts.

For when a *Fluid* is preſſed from all Sides, it endeavours to recede from that Preſſure; from whence that Force of receding will preſs all circumjacent Bodies, whether *Fluid* or *Hard*. V. G. Let a Drop of Water [*Fig.* 22.] as *a* be preſſed by the Finger D upon the Plane B C, it will not only preſs the Plane B C, but endeavour to recede towards the Parts B and C; and if there be any Body as F, which hinders its Motion, it appears that that Body is preſſed with all that Force by which it endeavours to recede towards B. After the ſame manner in the *Fluid* [*Fig.* 20.] A B C D let any Part be aſſigned as E, which by the foregoing *Prop.* is preſt by the upper Part G, and endeavours to recede towards the Parts F K, there-

fore

fore it muſt needs be that it preſſes F and K with all that Force by which it recedes towards theſe Parts A B C D.

COROLL.

Hence the lateral Preſſure is according to the Height of the incumbent *Fluid*.

SCHOLIUM.

Hence it's eaſily underſtood why *Flasks* well ſtopt, and only full of Air, being let down into the Sea (by ſome Weight tied to them) are broken, *viz*. by the great Weight of the incumbent Water, which neither the Soundneſs of the *Flasks*, nor the included Air is able to reſiſt.

EXPERIMENT.

If you immerge a *Glaſs Tube* in Water, and ſtop the open End [*Fig*. 24. *Plate 3d*.] with your Finger, to hinder the Water from falling out of it again, and immediately take the *Tube* of Water and put it a pretty way into a Veſſel of *Oil*, ſo that the upper-moſt Surface of the Water may be be-

below the Surface of the *Oil*, the *Oil* will force the Water up; for the *Oil* at E F being more preſſed by the *Columns* of *Oil* G and H, than it is by the incumbent Water at M, will be forced upwards, and it will make the Water at M to aſcend, till the *Fluid* in the *Tube* preſſes as much on the Surface M as the *Oil* at G H does on the Surface E F.

Now becauſe Water is heavier than *Oil*, the Water in the *Tube* will not riſe ſo high as the Surface of the *Oil*, for the Water being heavier, a *Column* of a leſs Height will preſs as much on M as the *Columns* G H preſs on E F.

Hence we ſee that a lighter *Fluid* may preſs on one that is heavier.

Prop. III.

Fig. 20. *Plate* 3.] If all the Parts F E K of an homogeneous *Fluid*, as A B C D, which lye under the ſame horizontal Plane, are equally preſſed; from ſuch a Preſſure there ariſes no Motion, for when the Preſſure is equal on all the Parts, they all will preſs each other with an equal Force; wherefore no one Part will yield to ano-

ther, but the under *Fluid* powerfully aſſiſted by the Bottom of the Veſſel, reſiſts their Preſſure downwards; therefore, from ſuch a Preſſure there ariſes no Motion.

COROLL.

Hence alſo the Parts of an homogeneous *Fluid* are at reſt, and not moved by any inteſtine Motion; for ſince all the Parts equally reſiſt, one Part will not yield to another, and therefore are not moved. Contrary to *Des Cartes*'s Opinion, who held, *that* Fluidity *conſiſts in a continual and various Motion of the Parts.*

Prop. IV.

Plate 3. *Fig*. 20.] If any Part as E, of the *Fluid* A B C D is more preſſed than the reſt, it will drive both the Parts under it, and thoſe on every Side (*a latere*) out of their Places. For if the Parts of a *Fluid* eaſily yield to any Force impreſſed (by *Def.* 1.) it appears that the Parts F G which are next to E, will give place to it preſſing with a greater Force, from whence E flows into their Places K E D.

E X-

EXPERIMENT.

Fig. 23. *Plate 3d.*] Fill a *Tube* with *Oil*, and immerge the Bottom a little way in a Veſſel of *Water*, (the top of the *Tube* being kept ſtopt with your Finger) ſo that it ſtand a good way above the Surface, as at *n*, then the *Water* at *m* being preſſed by a high *Column*, will be more ſtrongly preſſed by the incumbent *Oil*, than E and F are by the incumbent *Water*; conſequently it will (after your Finger is removed from the top of the *Tube*) thruſt the *Water* at E and F out of its Place to give the *Oil* liberty to deſcend, and then you will ſee the *Oil* come out of the *Tube* in Drops, and then mixing with the *Water* it will aſcend and ſwim on the top.

Prop. V.

Plate 3d. Fig. 20.] If the Parts E of the *Fluid* A B C D be leſs preſs'd than the reſt, the Parts next to it as F G K being more preſſed, will thruſt it away and poſſeſs its room, and the Part E will riſe until the Preſſure of the Parts next to it be equal to its own Preſſure.

 For

For, ſince the Part E being leſs preſſed, cannot reſiſt the reſt preſſing ſtronger, it will yield to them by the 1. *Def.* and that always till it come to ſuch a Place, where the Preſſure of the Parts next to it be equal to its own Preſſure, where, by the *3d Prop.* it will reſt; but if it be a *Fluid*, and it happen that it reſts not under the Superficies, it will ſpread it ſelf all over the upper Superficies.

COROLL.

Hence if the Parts of a *Fluid* are in *Æquilibrio*, they are all equally preſſed under the ſame horizontal Planes.

EXPERIMENT.

Fig. 24 *Plate* 3.] Take a *Tube* and fill it a little way with *Oil*, and ſtop it as before, the *Oil* will ſtill remain in the *Tube* (being kept there by the Preſſure of the Air) immediately immerge the *Tube* in *Water* (which may be tinged with *Cocheneal* for the better Diſtinction) a good way below the Surface of the *Oil*, then take off your Finger, and you will immediately ſee the *Water* thruſt up the *Oil* above the Surface. The Reaſon is this: Suppoſe the *Oil*

in

in the *Tube* only to reach to *c*, then the Surface of the *Water* at *g* being only preſſed with the *Column* of Oil *c g*, and the Water at S and R being preſſed with higher Columns *d* S, *b* R the Parts of the *Fluid* at S and R, being more preſſed than the Parts *g*, will thruſt *g* out of its place, and make it aſcend in the *Tube*, and preſs upon the *Oil* which will continually riſe, till when it is at *a* the Oil and Water in the *Tube* preſs as much upon *g*, as the Columns *d* S, *b* R do upon S R. Now, becauſe the Oil is lighter than Water, the Column of Oil which preſſes as much on the Surface *g*, as a Column of Water would do, muſt be higher than the Column of Water; and therefore the Oil will riſe higher than the Surface of the Water to *a*.

If we try this *Experiment* with Water in Oil, the Water in the Tube will be below the Surface of the Oil, as at G H, ſo much as it is ſpecifically heavier. Hence we ſee a higher Fluid may preſs on one that is heavier.

The ſame will hold if a Solid preſs upon the Fluid; nay, even Lead may be made to ſwim in the following Manner. Take a Cylindrical Glaſs open at both Ends, and ground at Bottom; then

holding

holding a ſmooth Weight of Lead cloſe to the ground End of the Glaſs (with wet or oiled Leather upon the Lead, that no Water may get into the Glaſs betwixt it and the Lead) plunge the whole in Water till the Depth of the Lead in the Water be about twelve times its Thickneſs, or ſomething more, and the Water will keep the Lead from ſinking; puſhing againſt it by a Force equal to the Exceſs by which the Water (which is by the Veſſel hindered from preſſing immediately under the Lead) exceed the weight of the Lead. But if the Veſſel be raiſed till the Lead be but nine or ten times its Thickneſs below the upper Surface of the Water, the Lead will leave the Glaſs and ſink down, moving as it leaves the Glaſs with a Force equal to the Exceſs, by which it exceeds the Water that it keeps out from preſſing immediately under the Lead; becauſe a *Pillar of Water* of the Diameter of the Lead ought to be twelve times its Thickneſs, to be equal to it in Weight. Thus will any *Metal* be made to ſwim, if they are ſunk in the Water ſomething deeper than as many times their Thickneſs, as they are ſpecifically heavier than Water; always ſuppoſing the *Glaſs* to hinder the Water from coming in to ſink above them.

them. As for *Ex. Braſs*, *Copper*, *Gold*, *Antimony*, *Iron*, will ſwim if plunged above 8, 9, 18, 4, and 7 times their Thickneſs, becauſe they are about 8, 9, 18, 4, and 7 times ſpecifically heavier than Water.

This Experiment *will ſerve to illuſtrate the 2d and 4th* Propoſitions.

Prop. VI.

Plate 3. *Fig.* 21.] Let A B C D be a Veſſel of ſuch a Figure, as that its *Baſis* C D be greater than its upper Superficies A B. I ſay that a *Fluid* contained in ſuch a Veſſel preſſes the *Baſis* C D as much as a *Priſm* or *Cylinder* E C D F, whoſe *Baſis* is C D, and Height E C, equal to the *Baſis* and Height of the Veſſel A B C D, would preſs it; for ſince by the *Coroll.* of the *5th Propoſition* all the Parts of a *Fluid* comprehended under the ſame horizontal Planes, are equally preſſed; it appears that the Parts at C N and D M are preſſed as much as the Parts at M N, but the Parts at M N are preſſed by the *Priſm* or *Cylinder* A B M N, from whence it appears, that the Parts at C N and D M are as much preſſed as the *Priſm* or *Column*

E

ECNADMB would preſs them; wherefore CD is preſſed as much as it would be if the *Fluid* ECDF lay upon it.

COROLL.

Hence ſince *Weight* is as *Preſſure*, it manifeſtly appears that the *Baſis* CD ſuſtains the ſame *Weight*, which it would if preſſed by ECDF, which (tho' it ſeems a Paradox) this *Experiment* confirms.

EXPERIMENT.

Plate 4. *Fig*. 1.] Let ABCD be a *Cylinder* of *Braſs*, exactly filled with a moveable *Baſis*, ſo exactly contrived that no *Water* may run out between it and the Side of the *Cylinder*; let *a* be a long *Braſs* Tube continued to the top of the *Cylinder*; let a Rope that is tied to one End of the Balance, and runs thro' the Tube, be fixed to the Middle of the *Baſis* at *a*, then pouring *Water* in at E, ſo as to fill the *Cylinder* at AB, ſee what Weight in the Scale K will be required to move or raiſe the *Baſis a* preſſed by a Column of *Water* ABCD. As for *Ex*. Suppoſe Ten Pounds after this fill the Tube with *Water* up to the top, which

which if it be three Times longer than the *Cylinder*, you will find that there will be need of three Times more Weight to raiſe the *Baſis*, than when it was preſs'd by only the *Column* of *Water* A B C D; whereas it was then raiſed by ten Pounds, it will not now be raiſed by leſs than forty, which will be the Weight of a *Column* of *Water*, whoſe *Baſis* is equal to the *Baſis* G; and whoſe Height is equal to that of the *Tube* and *Cylinder*, *viz*. G C D H. There are ſeveral ways of proving this *Paradox*.

Horſe-Hair is reckoned to be a Body that comes neareſt the *Specifick Gravity* of *Water*.

Prop. VII.

Plate 4. *Fig*. 2.] If in a Fluid, as A B C D be let down a Body E, having a *Specifick Gravity* equal to that of the Fluid, the Body will be all covered in the Fluid, and will retain any given Poſition.

For if any Part of it as E ſhould remain above the Superficies of the Fluid, that Part of the Fluid, *viz*. which is under the Body E would have a greater Preſſure than the Parts I and K, which are only preſſed by the incumbent Fluid. For the

immersed Part of the Body E presses H of it self, as much as the Fluid in its room would do; so that the Part which is out of the *Water* added to the Pressure, will force the Part H of the Fluid out of its Place, by the 4*th Prop.* therefore the Body E will descend and be all immersed; and therefore, as in *Fig.* 9*th.* when the Body has an *intense Gravity*, equal with that of the Fluid, both the Parts under the Body, and those under the Fluid in the same horizontal Plane, are equally press'd; so that by the 3*d Prop.* there arises no Motion from such a Pressure: And since the same Reason holds good in every Position of the Body, it is manifest that it retains any one that is given it, K E D.

Prop. VIII.

Plate 4. *Fig.* 9.] If in a Fluid, as A B C D be immersed any Body as E, specifically heavier than the Fluid, the Body will descend to the Bottom, but with a Force equal to the Excess by which the *Gravity* of the Body exceeds the *Gravity* of so much of the Fluid as is equal to it in *Bulk*.

For if the Body and the Fluid were both of the same *Specifick Gravity*, the Body would not descend

deſcend by the *7th Prop.* But when it is heavier than the Fluid, the Parts H under the Body are preſſed ſtronger than thoſe under the Fluid; wherefore by the Exceſs of that Preſſure, the Parts H will be thruſt out of their Places, therefore by the ſame Exceſs E will deſcend K E D.

COROLL. I.

A Body immerſed in a Fluid loſes as much of its *Gravity* as is the weight of a Portion of the Fluid, equal to it in Bulk; for *Gravity* is a Force which puſhes a Body downward. Now ſince a Body deſcends with that Force only, by which it exceeds the *Gravity* of an equal Bulk of the Fluid, it appears that it gravitates in *Water* with this Force alone.

EXPERIMENT.

Weigh a piece of Lead in the Air, ſuppoſe twelve Pounds; and afterwards weigh it in the *Water*, and find how much it loſes of its weight, ſuppoſe 17 Oz. Obſerve alſo how high the Lead raiſes the *Water* when put into it, then take out the Lead and put in 17 Oz. of *Water*, and you will find that the *Water* added will riſe as high in

the Veſſel as the Lead raiſed it before; and therefore the Weight that a Body loſes in the *Water*, is juſt equal to the Weight of as much *Water* as is equal to the Body in Bulk; what Weight the Body loſes the *Water* gets. For *Ex.* Suppoſe a Veſſel of *Water* weigh ten Pounds; if we hang a twelve Pounds Weight in that Veſſel by a String, ſo that it may touch neither Bottom nor Sides, the Veſſel of *Water* will weigh ten Pounds and ſeventeen Ounces, which is juſt the Weight that the Lead of twelve Pounds loſes, and what the Lead loſes the Body gains.

COROLL. 2.

Two *Bodies* which are of different *Specifick Gravity*, as *Gold* and *Silver*, *Æquiponderous* in Air, or rather in *vacuo*, being immerſed in a Fluid, that which is of the greateſt *Specifick Gravity* will preponderate. For ſince every *Body* immerſed in *Water* loſes of its *Gravity*, as much as is the *Gravity* of a Portion of the Fluid, equal to it in Bulk; it appears that that which takes up the leaſt room, that is, that which is ſpecifically heavier, loſes leſs of its *Gravity*, and ſo preponderates.

E X-

EXPERIMENT.

Take a *Crown-Piece* of *Silver*, and a Piece of *Lead* of the ſame weight; when they are weighed in the Air, afterwards weigh them in the *Water*, and the *Lead* will preponderate.

COR. 3.

Bodies are eaſier lifted up in *Water* than in *Air*.

COROLL. 4.

Hence the Weight of any *Fluid* is eaſily found, *viz.* by immerſing a *Cubical Foot* of *Lead* into it, and its Difference between its Weight in the *Fluid*, and its Weight in *vacuo*, is the Weight of the *Fluid*.

Prop. IX.

Plate 4. *Fig.* 3.] If in a Fluid as A B C D, the Body ſpecifically lighter than the Fluid be immerſed, it will not be covered, only ſo much of it as is equal to a Portion of the Fluid, which is as heavy as the whole Body.

For

For if the whole ſhould be immerſed, it appears that the Parts of the Fluid under it, are leſs preſſed than thoſe under the ſame horizontal Plane are by the incumbent Fluid; becauſe the Gravity of the Body E is leſs than the Gravity of an equal Bulk of the Fluid: Therefore by the *5th Prop.* the Parts under E will riſe till they come to ſuch a Place, as where the Preſſure of the Fluid A I K D is but equal to the Preſſure of E, that is, when the Preſſure of the Body E is equal to the Preſſure of as much of the Fluid as would be put in the Place of the ſubmerſed Part.

COROLL. 1.

Hence ſince the *Specifick Gravities* of *Bodies* are reciprocally as the Bulks of *Æquiponderons* ones; by the *4th Prop.* the immerſed Part of the Body E will be to the whole, as the *Specifick Gravity* of the Body to the *Specifick Gravity* of the Fluid.

COROLL. 2.

Therefore the Gravity of *Bodies* put in a Fluid is twofold; one True and Abſolute, the other Relative and Apparent; by the firſt Sort of Gravity

vity the Parts of Fluid and of Solid Bodies, gravitate in their Places; therefore the Weights being joined, they compound a Weight of the whole. By *Relative Gravity*, *Bodies* do not gravitate in their Places, that is, they do not preponderate one another, but hindering each others Endeavour to descend, they remain in their Places, as if they were not heavy; those things which are in the Air and do not preponderate, the common People do not think heavy, but those which do preponderate they esteem heavy, because they are not sustained by the weight of the Air. *Common Weights* are nothing else but the Excess of true Weights, above the weight of the Air; from whence also those things are commonly called light which are less heavy, and by yielding to the preponderant Air mounts upwards; they are comparatively light, not truly so, because they do descend in *vacuo*.

Thus also in *Water Bodies* which descend, or ascend by reason of their greater or less Gravity, are apparently and comparatively heavy or light; and their relative Gravity or Lightness is the Excess or Defect by which their true Weights exceed the Gravity of Water, or are extended by it.

A

A *Kettle* is cold at Bottom when the Water boils, because warm Water being ſpecifically lighter than Cold, the cold Water will deſcend to the Bottom.

COROLL. 3.

The immerſed Parts of unequal *Bodies* of the ſame *Specifick Gravity* in a *Fluid* heavier than themſelves, are to each other as the wholes.

COROLL. 4.

The immerſed Parts of equal *Bodies* having different *Specifick Gravities*, are to each other as their *Specifick Gravities*.

EXPERIMENT.

Take a piece of Wood and weigh it, then ſink it in a Veſſel as far as it will go with its own Gravity, and obſerve how high it riſes the Water in the Veſſel; having taken out the Wood, pour as much Water in the Veſſel as is equal to the weight of the Wood, and this will riſe up to the ſame Surface that the Water did before the Wood was in.

Prop.

Prop. X.

Plate 4. *Fig.* 4 *and* 5.] If the ſame Body E be immerſe in different *Fluids*, heavier than it ſelf, the immerſed Part will be reciprocally as the *Specifick Gravities* of the *Fluids*.

For the immerſed part of the Body E in the Fluid A B C D is to the whole, (by *Cor.* 1. *Prop.* 8.) as the *Specifick Gravity* of the *Body* to the *Specifick Gravity* of the *Fluid*, and the whole is the immerſed part in the Fluid *a* B *c d*, as the *Specifick Gravity* of the *Fluid* to the *Specifick Gravity* of the *Body*; wherefore by 23 of *El.* 5. the immerſed Part in A B C D will be to the immerſed Part in *a* B *c d*, as the Gravity of the Fluid to *a* B *c d* to the Gravity of the Fluid A B C D K E D.

Hence appears a Method of finding out, whether any Quantity of *Salt* is contained in *Water*, by the Aſſiſtance of an *Inſtrument* made in *Glaſs*, repreſented in *Fig.* 20. *Plate* 2*d*. And ſince *Salt-water* is heavier than *Freſh*; find firſt how deep the *Inſtrument* ſinks in *Freſh-water*, and if in trying other Water it is leſs immerſed, it's certain

that *Salt* is contained in it, as being heavier, and by how much the leſs it is immerſed, by ſo much the more the Salt is in the Water.

The Excellency of Liquors as *Wine*, for Inſtance, is found out by the ſame *Inſtrument*; for by how much the lighter ſuch Liquors are, they are commonly eſteemed ſo much the better; but their Gravity is found out after the ſame manner.

Prop. XI.

To find what Relation the Specifick Gravity *of a* Fluid *and a* Body *given, unmerſed in it, have to each other.*

In the firſt place, ſuppoſe the Body to be ſpecifically heavier than the Fluid, and let its Weight be found in *Vacuo*, and then put it in the Fluid: As the Weight of the Body will be to the Exceſs (by which the ſame *Body* weighed out of the Fluid, exceeds its own Weight in the Fluid) ſo the *Specifick Gravity* of the *Body* will be to the *Specifick Gravity* of the Fluid. For the *Specifick Gravity* of *Bodies* equal in Bulk, are as their Weights; but the Weight of a Portion of the Fluid equal in Bulk to the *Body* it ſelf, by *Cor.* 1. *Prop.* 8. is

that

that Difference of the Weight; therefore theſe being given, the Relation between the Specifick Gravities of the Body and the Fluid will be given alſo.

But if the *Body* immerſed be ſpecifically lighter than the Fluid, the Specifick Gravity of the Fluid will be to the Specifick Gravity of the *Body*, as the whole *Body* to the immerſed Part of it, by *Cor.* 1. *Prop.* 9.

Prop. XII.

Plate 2. *Fig.* 18.] *The Solid Bodies as* A *and* B *being given, to find that Relation their* Specifick Gravities *bear to each other.*

Let the Relation of the Specifick Gravity A to the Specifick Gravity of the Fluid D, be found by the former *Prop.* and let the Relation of the Specifick Gravity of the Fluid D to the Specifick Gravity of the Solid B be found alſo; from whence by 20. *El.* 5. the Relation of the Specifick Gravity of the Solid A to that of the Solid B will be given.

Prop. XIII.

Plate 4. *Fig.* 6.] If upon the Fluid A B C D, another Fluid as E A D F be poured ſpecifically

higher than the former, it will not be immersed in the Fluid, yet it will press its Superficies by its Gravity.

For since the Fluid A B C D is specifically heavier than the Fluid E A D, its Force of tending downwards will not be exceeded by the Force of the Fluid E A D F; wherefore the Fluid E A D F cannot descend below A B C D; yet since it is heavy, it is manifest that it presses the Superficies A D with its Gravity.

COROLL. I.

Hence the Pressure of any Fluid poured in, supposing it to be Homogeneous, and of the same Density every where, is always according to its Height.

COROLL. 2.

By how much specifically heavier the Fluid is, by so much the greater is its Pressure.

COROLL. 3.

The Superficies of every Fluid is pressed by Air.

Prop.

Prop. XIV.

Plate 4. *Fig.* 7.] If the Superficies of the Fluid A B C D be preſſed by an incumbent Fluid, but the Part G freed from the Preſſure (which may be done by the Aſſiſtance of a *Tube*, as *l m n o*, the Fluid G will riſe above the Superficies A *m* D *n*, and that to ſuch an Height, as that the Superficies *m n* may be preſs'd with as great a Force as A *m* D *n*; that is, it will riſe up to *p q*. For ſince the Parts *p q* of the Fluid are leſs preſſed than the reſt, it will riſe by the 5 *Prop.* and that until *m n* be preſſed with as great a Force as A *m* and D *n* under the ſame horizontal Plane.

COROLL. 1.

Hence the Fluid *m n p q* which aſcends, has as much Gravity as the Quantity *m n r s* of the Fluid E F A D would have of the ſame Height as E A and F D.

COROLL. 2.

Therefore the Specifick Gravity of Fluids are reciprocally to each other as the Bulk of the aſcen-

aſcended Fluid as $pmnq$ to the Bulk $nmrs$, or when theſe two *Bodies* have equal *Baſes* reciprocally as their Heights.

SCHOLIUM.

Since Air preſſes the Superficies of all *Fluids* by its Gravity, by *Cor.* 3. *Prop.* 13. If any Part ſhould be free from the Preſſure, it is manifeſt from the foregoing *Prop.* that the *Fluid* will aſcend above that Superficies which is not preſſed with the Air, until it preſs the Superficies under it, with as much Force as the reſt of the Superficies is preſſed by the incumbent Air.

And this *Prop.* is of very great uſe in *Hydroſtaticks*, for by its Aſſiſtance all the *Phænomena of Nature* that uſed to be attributed to the Abhorrence of a *Vacuum* are eaſily explained. Nay, many things are drawn from it for the neceſſary Uſes of Life, as *Syringes*, *Pipes*, and other ſuch like *Machines*. But before we treat of theſe things, it will not be amiſs to ſpeak a few Words of the *Torricellian Experiment*, and to ſhew the Cauſe of it, from what has been above demonſtrated.

EX-

EXPERIMENT.

Take a Veſſel of *Water*, and immerſe a *Tube* (open at both Ends) into it, then pour Oil upon the *Water*, to the Height of four or five Inches, which will raiſe the *Water* in the *Tube* ſo high, that it may preſs as much on the Surface of the *Water* under it, as the Oil does on the reſt of the Surface; let the ſame *Experiment* be tried with ☿ and *Water*. Vide *Prop.* 4. & 5. [*Plate* 2. *Fig.* 19.] Take a Drinking Glaſs, and turn it ſo in the *Water*, the Air being turned out; if the Glaſs be raiſed perpendicularly, the *Water* will aſcend in it above the Surface of the ſtagnant *Water*, as at B.

The Air does not only gravitate on the Surface of *Fluids*, but alſo upon all *Solid Bodies*, as may be proved from the Coheſion of two flat Pieces of *Glaſs* or *Marble* exactly poliſhed and ground together.

That this depends upon the Preſſure of the Air is plainly evinced, by trying the *Experiment* in the Recipient of an *Air-Pump*; for after an Exſuction or two of Air the *Marbles* drop aſunder.

Another

Another *Argument* for the Pressure of the Air, may be taken from the Recipients sticking to the Plate upon which they are fixed so closely, that after two or three Exsuctions it requires a considerable Weight to pull it away.

Prop. XV.

Plate 4. *Fig.* 8.] To shew the *Torricellian Experiment* and explain the Cause of it; let A D the horizontal *Superficies* of the *Quick-Silver* contained in the Vessel A D be exposed to the Pressure of the internal Air, and the *Tube* P C stopped at P and open at C, be filled with *Quick-Silver*; after this turn it, and immerse its *Orifice* C under the *Superficies* of the *Quick-Silver* contained in the Vessel A D, keeping its *Orifice* C stopped with your Finger, until that it be so immersed that the *Quick-Silver* do not run out by turning the *Tube*; and then unstop it, holding it in that Position. Now *Experiment* makes manifest, that the *Quick-Silver* in the *Tube* C P will not descend below the Height of Twenty-seven or Twenty-eight Inches; and if the length of the *Tube* be less than Twenty-seven or Twenty-eight Inches, the

the *Quick-Silver* will not deſcend at all, until its Height *m c* be Twenty-ſeven or Twenty-eight Inches (there being left within the *Tube* P *m n*, a *Vacuum* of Air and *Quick-Silver*) where it will remain. The Reaſon of this *Experiment* appears from the foregoing *Prop.* For ſince the *Superficies* of *Quick-Silver* A D, is preſſed by the ſuperincumbent Air, but its Part C is freed from that Preſſure; it muſt needs be, that the Height of the *Quick-Silver* in the *Tube* C P be ſo great, as that the *Superficies* C ſuſtain the ſame Preſſure from the incumbent *Quick-Silver*, as the reſt of the *Quick-Silver* does from the incumbent Air.

EXPERIMENT.

If we immerſe the *Tube* thus filled, in *Water* inſtead of *Mercury*, the *Mercury* in the *Tube* will deſcend, and the *Water* will aſcend to the top of the *Tube*, *per Prop.* 4.

N. B. *If we incline the Tube towards the Horizon, the ☿ will riſe higher, and always keep the the ſame ⊥ height; for in the inclined Poſition it does not preſs ſo much upon the ſubjacent ☿ as on the reſt, its Gravity acting purely againſt the Sides of the Tube.*

To prove that this deſcends upon the Preſſure of the Air, take a Glaſs *Tube* four or five Foot long, which has one End (inſtead of being ſealed *Hermetically*) tied over with a piece of *Bladder*; fill it up with *Water*, and immerge it in ſtagnant *Water*, you will obſerve the *Water* not to deſcend at all; but if with a Pin you make an Hole in the *Bladder*, the *Water* will immediately deſcend quite out of the *Tube*.

COROLL. 1

Hence a *Cylinder* of ☿ of Twenty-ſeven or Twenty-eight Inches, gravitates as much as a Column of Air, whoſe Height reaches to the top of the *Atmoſphere*, and whoſe *Baſis* is the ſame as that of the Column of *Quick-Silver*.

EXPERIMENT.

We may increaſe the Weight of the Air by ſinking the *Barometer* into another *Fluid*; to wit, put it into a long *Cylindrical* Glaſs, and afterwards pour Water on the Surface of the ſtagnant *Mercury*, and the ☿ will ſtill riſe higher in the *Tube*, according as the Preſſure of the Water increaſes.

About

About fourteen Inches of Water upon the ſtagnant *Quick-Silver* will raiſe that which was in the *Tube* about one Inch, there being Fourteen to One between the Gravity of ☿ and *Water*.

The *Tube* with ☿ being put into a long Receiver, the ☿ will fall down after the Air is pumped out.

The ſame *Experiment* may be tried with *Water* in the *Tube*, but the *Water* will not ſubſide ſo faſt as the ☿ did. And if in the *Tube* there be left a ſmall *Air-Bubble*, this *Bubble* will expand it ſelf and fill the whole Cavity of the *Tube*, even ſo much as to depreſs the Surface of the *Water* in the *Tube*, below the Surface of the ſtagnant *Water*.

COROLL. 2.

If Air were of the ſame Denſity at all Diſtances from the Earth, its Height could eaſily be found out; for as the Difference of the Height of the ☿ on the top of a Mountain, is to the Height of the ☿ at the bottom of the Mountain; ſo is the Height of the Mountain to the Height of the Air.

It is manifeſt that a *Cylinder* of Water of Thirty-two Foot gravitates as much upon a *Fluid* under it, as the Air does upon the other Parts of it; therefore Water can be ſuſtained at ſuch a Height by the Gravity of the Air.

SCHOLIUM.

I have ſaid that ☿ is ſuſtained at Twenty-ſeven, or Twenty-eight Inches; for the Gravity of the Air is various and mutable; ſometimes ☿ will remain Twenty-ſeven Inches, ſometimes Twenty-eight, and now and then it will aſcend to Twenty-nine or Thirty Inches; from whence it muſt needs be that the Gravity of the Air is changed proportionably to its Height.

By how much the heavier Air is, ſo much the eaſier can it ſuſtain Vapours raiſed by the Heat of the Sun; for Vapours are nothing elſe but watery Particles rarified by the Heat of the Sun; and therefore the ſame Particle of Water taking up a greater Space, becomes ſpecifically lighter than Air; from whence of Neceſſity that Particle muſt aſcend until it come to the Air, whoſe *Specifick Gravity* is equal to its own, where it muſt reſt; but the Gravity of the Air decreaſing, it muſt needs

needs be that the Vapours will deſcend, which by the Reſiſtance of the Air in their Motion, are formed into Drops of Water, from whence it cannot but Rain when the Gravity of the Air is leſſened; but when its Gravity is increaſed the Force is alſo increaſed, by which it is able to ſuſtain the Vapours, and that remaining the Air is clear. Hence it is that ſuch a *Tube* filled with ☿, and immerſed within the *Superficies* of ſtanding ☿ is uſed to ſhew the Gravity of Air and fair Weather which follows from it.

Prop. XVI.

The *Elaſtick Force* of Air incloſed in a Veſſel of the ſame Tenor with the ambient Air, performs as much as the Burthen of the open incumbent Air.

Let there be a *Tube* or a Veſſel, having an open *Orifice*, by which there may be a Communication between the internal and external Air; if then the adjacent Parts of external Air, be leſs preſſed than thoſe which are within the Veſſel, theſe will dilate themſelves by the *5th Prop.* until they come to an equal Force; but if the external adjacent Parts (by the Preſſure of the incumbent

bent Air) are more preſſed than thoſe within, thoſe that are within will be compreſſed, untill their *Elaſtick Force* is equivalent to the Force preſſing from without.

This appears from Mr. *Boyle's Experiments.*

COROLL. 1.

From this follows the Reaſon why we do not feel the Weight of the *Air*.

COROLL. 2.

From hence alſo we know why we do not feel the Weight of *Water*.

COROLL. 3.

Plate 4. *Fig.* 13.] Let C D be a *Pipe* or curved *Tube* open at both Ends, one of which, as C is immerſed in Water, or any other *Fluid*; the other as E, being longer than C from the *Curve*, hanging without the *Fluid*. If then by Sucking, the Liquor comes to E, until it runs out, it will continue running, altho' you do not ſuck it, till the Liquor in the Veſſel be either all drawn out, or wants a due Height; yet upon this Condition, that

that the *Orifice* E be lower than the *Superficies* A B of the Liquor in the Veſſel; for the *Air* being ſuck'd out of the Tube into the Thorax, the *Fluid* under it is forced into the Pipe, by the Preſſure of the external incumbent *Air*, by the preceeding *Prop.* therefore the *Fluid* will riſe to the top D, until there is an *Æquilibrium* with the Preſſure of the external *Air* (ſuppoſe the Height I G) that is, in ☿ about Twenty-nine Inches, in Water about Thirty-three Foot, and ſo in other Liquors proportionably according to their Gravity, and will run out ſo ſoon as it finds a Paſſage, becauſe the Water gravitates in the longer Tube; and the Reaſon why D E ought to be longer than D C, is, becauſe if it were otherwiſe, both C and E would be preſſed equally by the Atmoſphere; if D E ſhould be ſhorter, the *Fluid* would be carried contrary; but if D be higher than I, the *Fluid* will be forced upwards as far as I, but not farther.

Take

Take a *Tube* of this Shape, open at ABC, and having immersed the Ends B and C into two different small Vessels full of *Water*, put the whole into a Cylindrick Jar of Glass, then pouring in Oil of Turpentine up to D, above the bent Part of the Tube, and the Water will run out of the Vessel A into the Vessel B, which shews that a competent Pressure of a lighter *Fluid* will make Water come over by a *Syphon*, even tho' the Air comes in at G; and this shews plainly that the *Fuga Vacui* has nothing to do in this *Experiment* and others of the like Nature.

EXPERIMENT.

Plate 6. *Fig*. 4.] Take a Receiver-Tube with the one End longer than the other, and pour *Water* in till it rises in both to the Height A; afterwards put your Finger on the *Orifice* A, and pour in Water at B, till it rise to the top; then put your Finger upon B, and leave the *Orifice* open, and the *Water* will not run out at A; but if you take off your Finger, the Liquor will run out at A till

till it has ſubſided in the Leg B down to the Level of the *Orifice* at A.

☿ will riſe the ſame Way, but not to the ſame Height, ſince it will riſe no higher than in the common *Baroſcope* ; that is, fourteen times leſs than *Water*, it being fourteen times heavier. ☿ riſes but to Thirty Inches, *Water* to about Thirty-three Foot.

If the *Romans* had known that the Preſſure of *Air* could raiſe *Water* to ſuch an Height, they needed not to have been at the Trouble of Cutting thro' Mountains to make their *Aquaducts* level.

SCHOLIUM.

The ancient *Philoſophers* ridiculouſly explained this by the Abhorrence of a *Vacuum*, in the place of which now deſervedly ſucceeds the *Æquilibrium* of the *Air*. *Galileus* firſt thought of it, and *Torricellius* maintained and proved it.

COR. 4.

Plate 4. *Fig.* 12.] The ſame thing holds good of the *Pump*, which is made of a long Piece of Timber cut Cylindrically within, and is immerſed

in the *Well*, the upper Part of which ſtanding above the *Superficies* of the Water; which Water is not to be ſuppoſed free from the Preſſure of the Air, but expoſed to it (for otherwiſe the Water will not be thruſt upwards) and at ſome Part of the Hollow of the Pump there is fixed a Piece of Wood acroſs, in the Middle of which there is the Hole D, thro' which this Water aſcends; and over this Hole there is a *Valve* or *Clack* as E, ſo placed acroſs, as to open or ſhut according to its being preſſed from above or below; alſo a *Bucket* as F G, let down from above by the Rod or Handle (ſo fitted to the Sides of the hollow *Cylinder*, as that the *Air* can have no Paſſage between) which alſo hath a Hole in the Middle of its Bottom, and a *Valve* G fitted to it, as hath D E. Things being thus ordered, while by moving the Handle the *Bucket* is drawn up (the *Air* being upon it, and by that means there will be a leſs preſſure of *Air* upon the Water below the *Bucket*) the Water in the *Well* being preſſed by the ambient *Air* will be forced up into the Hollow of the *Pump* through the Hole D (opening the *Valve* E) as far as the Bottom of the *Bucket* (provided it be not higher than I, the top of the

Æqui-

Æquilibrium) as being free from any Preſſure from above, and thruſt up from below; but on the contrary, by turning the Handle the other way, the *Bucket* is preſſed down, and preſſes the Water immediately under it, which aſcends thro' G D; by this Depreſſion E is ſhut and G opened, thro' which the Water having got above the *Bucket*, is drawn up with the *Bucket*; when it is drawn back (the *Valve* G being ſhut) and finding Paſſage flows out at H, then Water riſing again at D, ſucceeds as before in the place of the *Bucket* that is drawn up, and ſo continually.

Prop. XVII.

Concerning the Elaſticity of the Air, and ſome Effects depending upon it.

The *Elaſtick Force* of the *Air* is that by which a compreſſed Quantity of *Air* endeavours to expand it ſelf into a greater Space; and ſince the *Air* at the *Superficies* of the Earth is much preſſed by a great Weight of the incumbent *Air*, it muſt needs be that it will endeavour to recede from that Preſſure every way, and ruſh into whatſoever Space it finds free from Preſſure, where by

its *Elaſtick Force* it will expand it ſelf equally, and uniformly poſſeſs all the given Parts of this Space.

EXPERIMENT.

Let a *Bubble* filled with *Air* of the ſame Tenor with the outward *Air*, be *Hermetrically* Sealed, then heat it at the Flame of a Lamp, and the *Air* being expanded by Heat will burſt the *Bubble.*

If any Elaſtick *Body* be compreſſed by a ſuperincumbent Weight, it will endeavour to expand it ſelf equally on all Sides by its Elaſtick Force; and ſo equally puſh the Weight upwards, and the Table by which it is ſuſtained downwards.

Plate 6. Fig. 16.] But if inſtead of the Weight be put any thing that may reſiſt the retributive Force of the *Body*, then the Elaſtick *Body* will endeavour to expand it ſelf after the ſame manner which it did at firſt, and ſo will puſh the Table by which it is ſuſtained with the ſame Force alſo as at firſt; as alſo the thing which reſiſts it, tho' in vain. *See the Worm-Spring in the Figure.*

By

By how much the more an Elaſtick Body is expanded that reſiſteth any Compreſſion, by ſo much the leſs will its reſiſtive Force be, and ſo on the contrary; and therefore that Force is always equivalent to the Power that compreſſes it. Therefore the Denſity of the Air is always as the Force preſſing it; ſo that ſince the Air within is retained in its Denſity by the Weight of the ſuperincumbent Air, if a double Weight be applyed, it will become twice as thick, and be compreſſed in half the Space: If it be compreſſed with thrice the Force, it will be forced into three times leſs Space; ſo likewiſe if half of the incumbent Air be taken away, the compreſſed Air will expand it ſelf into twice the Space it had whilſt compreſſed, *&c.*

Hence ſince *Air* contained within the Walls of an Houſe, is of the ſame Denſity with the external *Air* with which it communicates, it will endeavour to relax it ſelf equally with the external *Air*, and will preſs the *Superficies* of *Fluids* with the ſame Force as if thoſe *Fluids* were immediately expoſed to the whole incumbent *Air*; and therefore *Air* within a Houſe will keep ☿ at the ſame Height in the *Torricellian* Tube, as if it was ex-

exposed to the Weight of the whole incumbent *Air*. Nay, some Part of the *Air* of the same Density with the external *Air* shut up in a Vessel with stagnant ☿, will by its Elastick Force keep the ☿ in the Tube at the same Height as before.

EXPERIMENT.

Plate 2. *Fig.* 19.] Take a Drinking-Glass as A, and immerge it in Water, so that the *Air* may not get out of it; if you sink it all under Water the Cavity will not be filled, the *Air* within hindering the Ascent of the Water; which may be shewn by putting Paper into the Bottom of the Glass, which will not be wet; but if you set the Paper on Fire, the *Air* by Heat being somewhat expelled, the Water will rise a good way in the Glass. Upon this Principle *Diving-Bells* are made, by which divers descend to the Bottom of the Sea and Breath freely under Water; yet the farther the *Bell* is sunk the more the *Air* will be compressed. When it is about Thirty-three Foot under Water, the *Air* will be compressed to half the Space which it was before; this sometimes breaks their Blood-Vessels and makes them Bleed at Mouth Nose and Eyes.

Take

Take a Mortar and bind a Piece of Leather on the Mouth of it, then take a Cupping-Glaſs, and having rarified the Air by Heat, immediately fix it on the Leather, to which it will adhere very ſtrongly, and the Leather will ſwell within the Glaſs, becauſe the Air in the Mortar has more Force than that which is rarified within the Glaſs, and therefore preſſes the Leather outwards. The Glaſs ſticks to the Leather, becauſe the external Air preſſes it down. Upon this Principle Cupping alſo is explained; the internal Air in the Blood rarifies, when the Preſſure of the external Air is taken away and diſtends the Skin, and makes it ſwell in the Glaſs. This is a Proof that there is a great deal of Air in the Blood.

Prop. XVIII.

To ſhew that the Aſcent of Fluids in Tubes after Suction, ariſes from the Preſſure of the Air. (*Plate* 4. *Fig.* 14.)

When a Man by the Muſcles of his Breaſt enlarges the Cavity of the Thorax, then the external Air finding room wherein to expand it ſelf, ruſhes in at his Mouth into his Lungs; ſo that if one Oriſice

Orifice of a Cube be in his Mouth, and the other immerſed in Water, then that Part of the *Superficies* of the Water, which is under the Tube, is free from Preſſure; and ſince the other Parts of the *Superficies* of the Water are preſt by the ſuper-incumbent Weight of the external Air, it muſt needs be (by *Prop. 5th*) that the Water will aſcend up the Tube, to wit, that the Parts under the Tube may be equally preſſed by the incumbent Water, as much as the reſt of the *Superficies* of the Water is preſſed by the incumbent Air; ſo that the Preſſure of the external Air upon the *Superficies* of the reſt of the Water, is the Cauſe that the Water aſcends up the Tube.

EXPERIMENT.

Plate 6. Fig. 15.] Take a Glaſs with a narrow Neck but without a Bottom as C, put a *Tube* in its Neck B, and cement them; then tye a *Lamb's* Bladder A to the End of the *Tube* within the Glaſs, and a large *Ox* Bladder D over the open End of the Glaſs, ſo that the Bladder may be forced inwards and drawn outwards; when the *Ox* Bladder is forced upwards, you will obſerve all the *Air* within the *Lamb's* Bladder wherein the *Tube* is inſerted

ſerted will be expelled. If you draw the *Ox* Bladder outwards, the *Air* will ruſh again into the *Lamb's* Bladder; after this manner Reſpiration is performed. The *Air* in the Cavity of the Thorax acts on the Lungs juſt as the *Air* in the *Ox* Bladder does on that of the *Lamb's*. If the open End of the *Tube* be immerſed in *Water* and the *Ox* Bladder drawn back, the *Water* will aſcend the *Tube* and fill the *Lamb's* Bladder. *Vide Prop.* 19.

Prop. XIX.

Plate 6. *Fig.* 11.] The Aſcent of *Water* in a Syringe, ariſes from the Preſſure of the external Air. *Viz.* When the *Tube* of the Syringe is immerſed in a Veſſel of *Water* at *q*, the *Piſton* being brought to R S is left void of Air, ſo that the Gravity of the external Air preſſing upon the Superficies *o p*, will make the *Water* aſcend in the *Tube* as high as R S, *viz.* that the Part of the Superficies of the ſtagnant Water at *q* may be preſſed by the incumbent *Water* in the Syringe with the ſame Force as the Superficies *o p* is preſſed by the incumbent Air.

A Deſcription of the AIR-PUMP *which Mr.* Boyle *made uſe of.*

I Shall not give a Deſcription of this Pump as it was when Mr. *Boyle* made uſe of it; becauſe it may be found in the firſt Part of Dr. *Harris*'s *Lexicon Technicum*, under the Word *AIR-PUMP.*

Plate 5. *Fig.* 1*ſt.* Repreſents the Pump with all its *Apparatus.*

D D is the Handle, which turning with the Nut B B, raiſes or depreſſes a Rack A A faſtned to the *Embolus* which raiſes and falls in the Cylinder, that is in the Body of the Pump, and cannot be ſeen in this Figure, but is repreſented by the third Figure as it is when taken out of the Frame.

C is a Plate of Iron ſcrewed down with four Screws upon the upper Part of the Pump, with a Notch filed in it for the back Part of the Rack to ſlide up and down in. It is alſo repreſented in *Fig.* 2*d.*

G F I is the Receiver open at both Ends.

G G is a ſmooth Braſs Plate laid on the Receiver with a wet Leather to keep out the external Air.

H is a Braſs Collar with Cork and Oiled Leathers, to let the Wire be drawn up and down without admitting the Air.

M N M is the Braſs Plate of the *Air-Pump*, on which the Receiver ſtands, with a wet Leather between the Plate and Receiver.

L L is a Board an Inch and an half thick, ſupported by the Iron Prop P which is raiſed at right Angles with the Side of the Pump *a b* to ſupport the Plate and Receiver when the Pump is made uſe of, otherwiſe it hangs down by means of the Hinges *a* and *b*.

U is a Braſs Pipe which lies in a Groove made in the Board, having a Communication with the Cylinder towards T, and with the Plate-Receiver and Mercurial Gage at N.

R is a Cock to let the Air into the exhauſted Receiver at pleaſure, which will run in from U to N, and ſo up the little upright Pipe into the Receiver.

O is a Glaſs Veſſel with ☿ in it, to receive the End of the Glaſs *Tube* or *Gage* N O, which has a graduated Piece of Box to ſhew how high ☿ riſes, and conſequently how much the Receiver is exhauſted.

S is a Board which ſupports the Veſſel O; *k k* are two Iron Screws to ſcrew the Pump to the Floor of a Room when the *Experiment* requires the Engine to be very ſteddy. They are alſo repreſented in *Fig*. 8.

E is a Cock to let out the *Water*, which muſt be kept at A B above the Cylinder when you uſe the Pump.

Fig. 3. Repreſents a Braſs Cylinder Cleft at the Bottom, for the *Piſton* repreſented by *Fig*. 4. to move up and down in. This Cylinder is ſcrewed down to the Stool of the Pump, being let down into the Box under A B; and there is a Cement made of Pitch and Brick-Duſt poured hot into the Box about the outſide of the Cylinder, which growing hard when cold, keeps it fixed.

T is a Hole to receive the Screw of the Pipe X Y, of *Fig*. 7.

Fig. 4. Repreſents the Rack A and *Embolus* B B, which makes up the *Piſton* of the Pump.

g g is a Braſs Plate fixed to the Rack about a quarter of an Inch leſs in Diameter than the inner Diameter of the Cylinder.

e e f f repreſent three or four round Pieces of *Sheep*'s Leather oiled very ſoft, about half an Inch more in Diameter than the Bore of the Cylinder, which being put on immediately below the Plate *g g*, will fold round the ſaid Plate up towards A when the *Piſton* is let down into the Cylinder.

c d is a ſtiff Piece of Shoe-Sole-Leather, whoſe Diameter is ſo nearly equal to that of the Cylinder's Bore, that it muſt but juſt ſlip down into the Cylinder without Friction.

B B is a Braſs Plate ſcrewed on at the Bottom of the Rack to keep the whole *Embolus* together.

When this *Piſton* is let down into the Cylinder below the Hole T, *Fig.* 1. the Air between T and U eaſily paſſes upwards by the Side of the *Embolus*, folding the left Leather up round the Plate *g g*, *Fig.* 4. but when you draw it from the Bottom no Air can get down below the *Embolus*, becauſe the Space between the Sides of the Cylinder and the Plate *c d*, is not large enough to let the Air fold downwards; ſo that the Preſſure of the Air and Water (which always lies on the *Embolus*, the more the

ſoft

ſoft Leather is preſſed to the Sides of the Cylinder, and therefore the Paſſage downwards round the *Embolus* muſt be cloſe ſtopped and keep out the Air, even tho' the Bore of the Cylinder ſhould not be truly round, as it happens in this, which by long uſe was become a little Oval.

Fig. 7. is a more exact Repreſentation of the Pipe U T of *Fig.* 1.

Y X is that Part which is to ſcrew into the Cylinder, having a ſquare Place at *a* to receive the Key of *Fig.* 5. which ſerves to turn all the Screws with its End *s*, or its End *r*.

Fig. 7. *c a b* is that Part of the Pipe which lies under the Plate that is ſcrewed on at *z*.

c is to ſcrew on the Part Y at T in *Fig.* 1.

a is a Screw to receive a Gage at the Place marked N in *Fig.* 1. It muſt have a *Valve* of a wet Bladder at the End of the Screw *b*, to which the Cock R is to be ſcrewed, by applying the Key Q *Fig.* 5. to the ſquare Place near *b*. *Fig.* 1.

Fig. 6. is the Braſs Plate a quarter of an Inch thick, which is truly flat, having a Braſs Rim round it to keep the Water from ſpilling when it is made uſe of in any Experiment.

P is a Hole in the Plate with a Screw to receive the little Pipe that ſtands upright under the Receiver.

N is the Plate with the Bottom upwards, ſhewing the Screw that fills the Hole *z* of the Pipe of *Fig.* 7. at the Place marked N in *Fig.* 1.

The Receiver is Exhauſted in the following manner.

When by means of the Handle or Winch D D the *Embolus* is raiſed above the Level of the Pipe U T in *Fig.* 1. (that is above the Hole T of the Cylinder in *Fig.* 3.) there is a *Vacuum* in the Cylinder under the *Embolus* and in the Pipe T L; *Fig.* 1. ſo that the *Valve* at T being no longer preſſed, the Air in the Receiver eaſily lifts it up by its Elaſticity, expands it ſelf ſo as to fill the void Cylinder. Then depreſſing the *Embolus* the Air comes up out of the Cylinder betwixt its Sides and the *Embolus*, and ſo comes bubbling out thro' the Water at A B, and raiſing the *Piſton* a ſecond time, the Air in the Receiver (tho' pretty much rarified already) lifts up the *Valve* at T, and runs into the Cylinder with Eaſe, to fill the void Space under the *Embolus*, and then is expreſſed out as be-

before; and ſo on till the Receiver is quite exhauſted, which may be known by the riſing of ☿ in the Gage; for when it is got up to the ſame Height as that at which it ſtands in the *Barometer*, the Receiver is exhauſted; becauſe the Preſſure of the Air being wholly taken off from that part of the Surface of ☿ which is directly under the *Tube*, the external Air will preſs upon the other Part of the Surface of the ſtagnant ☿, and ſo raiſe the ☿ in the *Tube*, till it makes an *Æquilibrium* with the Weight of the *Atmoſphere*.

N. B. *Tho' the external Air can come into the Pipe L T, it cannot get into the exhauſted Receiver, becauſe the Valve is ſhut the cloſer towards N M the more the Air preſſes upon it, being made only to open towards L.*

Experiments *of the* Air-Pump.

1. LAY your Hand on the Mouth of a ſmall Receiver, and by the Pump draw out the Air, and your Hand will ſwell within the Receiver; after a few Suctions the Air will preſs upon your Hand ſo that you cannot raiſe it.

2. Tie

2. Tie a Bladder to the Mouth of a Receiver, and extract the Air; then the external Air will depreſs the Bladder ſo much, that a Man's Strength will not be able to ſuſtain it.

3. Invert a Receiver, and tie a Weight to the Neck of a Bladder over the Mouth of the Receiver, and hanging on the outſide of it; having drawn the Air out of the Receiver, the outward Air will preſs ſo on the Bladder, as to thruſt it up into the Receiver, and raiſe the Weight.

4. Take a Piece of Glaſs and put it on the Mouth of a Receiver, having drawn out the Air, the Weight of the incumbent Air preſſing on the Glaſs will break it. By this *Experiment* we prove that the Air preſſes every way; for in what Poſition ſoever the Glaſs be, it will ſtill be broken by the incumbent Air

This is alſo proved by the ſtrong Coheſion of two flat Pieces of Glaſs or Marble, exactly poliſhed and ground together. As alſo by a Glaſs Recipient ſticking ſo cloſe to the Plate, after the Fxſuction of the Air, that it requires a conſiderable Weight to pull it away.

5. In the *Torcellian Experiment*, if the *Tube* with the *Mercury* be put into a long Receiver, the ☿ will fall down at the Exſuction of the Air.

6. The ſame *Experiment* may be tried with *Water* in the *Tube*; but it is obſerved that the *Water* will ſubſide ſo faſt as ☿.

7. If in the *Tube* there be left a ſmall Air-Bubble, the Bubble will expand it ſelf and fill the whole Capacity of the *Tube*, even ſo much as to depreſs the Surface of the *Water*, under the Surface of the ſtagnant *Water*.

8. A flavid Bladder, after the Preſſure of the external Air is taken off, dilates it ſelf as far as it can.

9. The Expanſion of the *Air* in a Bladder, will raiſe a Weight after the external *Air* is taken away.

10. A Bladder in which Weights are put to ſink it under *Water*, will riſe with its Weight after the Extraction of the external *Air*.

11. A Piece of Cork, to which is tied juſt ſo much Weight as to make it ſink all under *Water*, except the upper Surface of it, after the Air is extracted, will riſe higher; but when you let in the Air again it will immediately ſink towards the Bottom.

12. Fiſhes

12. Fishes in the *Water* in the Recipient will rise to the top of the *Water* when the Air is drawn out.

13. A Glass Bubble in which is left just so much *Water* as will sink it, after the Extraction of the external Air will rise.

14. If you draw out the Air from a square Glass Bottle, the Weight of the incumbent Air will break it to pieces.

15. If you put such a Bottle so closely stopt, that none of the Air can get out of it into the Receiver; after you have drawn out the external Air, that which is in the Bottle will so dilate it self, as to break the Bottle.

16. If you put two Brass *Hemispheres* together, shutting them one within the other, and only putting a Piece of wet Leather between them; if after this you pump out all the Air by the Help of a *Valve* at the Bottom of one of the *Hemispheres*, the Air cannot return into them; they will stick so closely by reason of the external Air, that it will require a very great Force to pull them asunder.

17. If you put any *Animal* into the Receiver, and pump out the Air, the *Animal* will immediately die.

18. If you take a Glaſs *Bottle* half full of *Water*, having a Glaſs Tube cemented in the Neck of it, one End of which is below the Surface of the *Water*, and the other being above the top of the *Bottle*, has a *Braſs* Top with ſmall Holes in it; if you put this into the Receiver, and pump out the Air, the Air in the *Bottle* will dilate it ſelf ſo as to preſs on the Surface of the *Water*, and raiſe it up in Spouts thro' the Holes of the Tube like a Fountain.

19. If you put a *Bell* ſo raiſed on a wooden Frame, that it may have room to move into a Receiver, and pump the Air out; then if you ſhake the Pump, ſo as to move the *Bell*, you will hardly hear the Sound of it.

This is a Proof that Sounds depend on the *Air*.

20. If you put a Glaſs of warm *Water* into the Receiver, and pump out the *Air*, the *Water* will perfectly ſeem to boil; the Reaſon is this, *viz.* The Elaſtick Force of the *Air* which is in the *Water* being increaſed by Heat, and not being preſſed by any external Air, it endeavours to dilate it ſelf, and by that means makes the Water bubble up; this is the way by which the *Air* may be almoſt all Extracted from the *Water*.

How

How to Condense the AIR, *so that you may put what Quantity you please into a Vessel.*

Plate 4. *Fig.* 10. IF you have a *Brass* Vessel half full of *Water*, with a Hole on the top of it, into which you may screw a little *Brass Pipe* at A, with a Cock at B, by which you may let in the *Air*; if on this you screw a Syringe which has at the bottom a *Valve*, by which the *Air* forced into the Pipe may be kept from returning again; and likewise a Curve Tube screwed to it at C, or only a small Hole and a *Valve* at the same Place, if then you draw up the Sucker of the Syringe, the Air will come in thro' the Tube D into the Syringe at C, and the *Valve* will then hinder it from returning. If then you open the Cock at B, and thrust down the Sucker, the Air will likewise descend into the Vessel, and by the *Valve* at the bottom of the Syringe be hindered from

from returning; by repeating this often, you may put what Quantity of *Air* you pleaſe into a Veſſel. If then you take off the Syringe, and ſcrew on in the place of it a Pipe with Holes, when you open the Cork, the *Air* preſſing hard on the *Water*, will force it up to a great Height, and will ſpout out in Figures according to the Holes of the Pipe.

Of BAROMETERS, THERMOMETERS, *and* HYDROMETERS.

TIS evident by what has been already proved, that the ☿ within the Tube gravitates as much on the Surface of the ſtagnant Mercury, as the *Air* does on the reſt of its Surface; and that a Column of *Air* reaching to the top of the *Atmoſphere*, is of the ſame Weight with a Column of *Mercury* of the ſame *Baſis*, and of an Height equal to the ☿ in the Tube. Now if the *Air* ſhould grow heavier, and preſs more on the Surface of the ſtagnant

nant ☿, then the ☿ in the Tube must rise higher, that it may be equal in Weight to a Column of *Air* of the same *Basis*, reaching to the top of the *Atmosphere*.

Hence it follows, that the Height of the ☿ in the Tube may be fitly applied to measure the Gravity of the *Air*, and on that Account an Instrument filled to that Purpose is called a *BAROMETER*.

Sometimes ☿ rises Thirty Inches, sometimes it stands at Twenty-nine, sometimes at Twenty-eight, sometimes it will sink to Twenty-seven, but seldom under, and of consequence the Gravity of the *Air* must alter proportionably.

Since Gravity is always proportionable to what the Matter weighs, it is impossible that the *Air* should change its Gravity, without changing its Quantity of Matter; and therefore some have thought this Difference of the *Air's* Gravity to proceed from its being more or less over-charged with Vapours; if this were the Case, there must be as many Vapours in the Air at a time, as are equal to Three Inches of ☿, for so much we find the ☿ rises or falls.

Now

Now ☿ is about Fourteen Times heavier than *Water*, and conſequently there muſt be in the Air at once, as many Vapours as will equal in length a Column of *Water* of Forty-two Inches high, and whoſe *Baſis* is equal to the Surface of the Earth; which is more than falls down in Rain during a whole Year; for a whole Year's Rain does not fill a Veſſel above Fourteen or Fifteen Inches high, as is obſerved in the Hiſtory of the *Royal Society* at *Paris*.

The Reaſon then why the Air is heavier at one time than another, ariſes from their being more Air in that part of the Earth's Surface, where the Air grows heavier, and this proceeds from *Winds*. *V. G.* If the *Wind* (which is nothing but a Stream of Air) ſhould blow over any Place, and the Air thus moved ſhould be kept in that Place by Mountains or Hills; or if two contrary *Winds* ſhould blow on the ſame Place, the Air would be heaped up in the Middle, and conſequently there being more Air, its Gravity will be increaſed; but if a *Wind* ſhould blow over a Country, the Air which is over that Place will be leſs in Quantity and conſequently lighter. Hence it is plain, that *Winds* are the only Cauſe of the Air's Gravity.

When

When the Air is heavy, the Sun acting on the Surface of the *Water* raiſes the Vapours from it; theſe being raiſed are ſpecifically lighter than Air, and conſequently they muſt riſe higher, till they come to an Air of the ſame Specifick Gravity with themſelves, where they will reſt; and a vaſt Collection of theſe Vapours from Clouds, ſo long as the Air continues heavy, the Vapours will be ſuſtained, and the Weather will be Fair. But if the Air turns lighter, the Vapours which were in *Æquilibrio* with it before, will now preponderate, and conſequently deſcend; in their Deſcent being continually checked by the great Reſiſtance of Air with which they meet, they will be condenſed; this Condenſation will ſtill grow more and more, till at laſt they are formed into Drops of Rain.

Hence it follows, that when the ☿ in the Tube is high, then the Weather will be Fair, and when it falls low, the Vapours then not being ſufficiently ſuſtained by the Air, muſt alſo fall, and the Weather will be rainy, and the Rain more or leſs according as the *Mercury* riſes or falls in the Tube.

Upon this Principle common *Weather-Glaſſes* are made; but to make the Change of the Air's Gravity more viſible, ſeveral Inſtruments have been contrived.

Plate 2. *Fig.* 21.] The *Wheel-Barometer* which conſiſts of a *Recurve* Tube A B C G E filled with ☿, the Gravity of the Air preſſing on the Surface E, there ſwims a *Leaden Ball* tied to a String, at the other End of which there is alſo tied a Weight, and the String runs on a Pulley at C, to which there is an Hand or Index applied, which moves along with the Pulley; and a large Piece of *Braſs* B F G E divided into any Number of equal Parts, marked 1, 2, 3, *&c.* When the ☿ falls at B it muſt riſe at E, and conſequently raiſe the *Ball* with it, whereupon the Weight at D will deſcend lower, and draw the String with it; and by this Motion the Pulley being turned, the Hand will ſhew the leaſt Variation of the Air.

This was invented by Dr. *Hook*; but this Inſtrument has one Inconvenience which makes it almoſt uſeleſs; for in damp Weather the String to which the Weights are tied, is contracted; and in dry it will grow longer; by this Motion it will move the Hand, when in the mean time the ☿ has

has neither risen nor fallen. A Watch String will do better with an *Iron Ball* instead of a *Leaden* one, which would be eaten up by the ☿.

Plate 6. *Fig.* 18.] 2. *HUGENS* contrived another Instrument after this manner. A B C D E F is a *Recurve Tube*, so made that the two Parts of it A B and D E have a much greater *Basis* than the rest, the *Tube* being filled with ☿, the Gravity of the Air pressing on the Surface at G, will sustain the ☿ to the Height A B, the Parts A B and D E being of an equal Height; if the ☿ fall an Inch at A B, it will rise as much at D E. Thro' the Orifice M on the Surface D E is poured Oil of *Tartar per Deliquium*, or *Spirits of Wine*, or some other Liquor that will not Freeze, to the Height F. Now when the ☿ rises at D E but an Inch, it will raise the Liquor which is poured into the Tube K I an Inch; and the slender Tube M P being of a much less *Basis* than the Tube K I, it must rise higher in M P. Thus if the *Basis* D E be ten times greater than O P, for one Inch that the Liquor rises in the Tube K I, it will rise ten Inches in the slender Tube M P. If ☿ falls one Inch in the Tube A B, the Liquor will rise ten in M P.

This Sort of *Barometer* has alſo an Inconvenience, which is, that as the Weather is Hot or Cold, ſo the Liquor in the Tube M P will dilate or contract it ſelf, and conſequently riſe or fall; whereas the ☿ continues ſtill the ſame Height.

3. Since ☿ in a Tube keeps always the ſame ⊥ Height, however the Tube be inclined; the beſt Contrivance for a *Barometer* ſeems to be this. A B C is a Tube (*Plate* 6. *Fig.* 3.) bended as in the Figure; B C is about Twenty-ſix Inches long, and A B ſo inclined that it may be Fifteen, whereas the ⊥ A E would not be above Five, according to the Structure, for every Inch the ☿ riſes in the ordinary Tube, it will riſe Three in the inclined one A B.

As *BAROMETERS* ſhew the different Changes of *Air*, as to Gravity and Levity, whence we eſtimate Fair and Foul-weather; ſo *Thermometers* are made uſe of to meaſure the various Temperature of the *Air*, as to Heat and Cold; to diſcover which there are ſeveral Inſtruments contrived.

Plate 6. *Fig.* 13.] 1. The Firſt is almoſt in the Form of a *Barometer*, only the upper End of the Tube

Tube ends in a large *Glaſs Ball.* This *Ball* is heated by putting near the Fire, ſo that the Air in it will be rarified, and ſomewhat expelled by Heat; then immediately the Neck of the Tube is to be immerſed in ſtagnant Water, which ſhould be tinged with ſome Colour that it may more eaſily be perceived. As *Air* in the *Ball* A begins to cool, it being more rare and leſs compreſſed than the external *Air*, the Water in the Veſſel will be impelled up into the Tube to B, by the Force of the external *Air*, and ſo compreſs the *Air* in A as much as the external *Air* is compreſſed. Now if the *Air* in A be afterwards again more heated, it will endeavour to expand it ſelf, and fill up a greater Space, and ſo preſs the Water down; but when it grows cooler it will be contracted into a leſs Compaſs, and the Water will again aſcend; ſo that when the Water in the Tube deſcends, the *Air* is hotter, and when the Water aſcends, the *Air* is cooler.

Plate 6. *Fig.* 1.] 2. The ſecond Kind of *THERMOSCOPE* is by a *Recurve Tube*, thro' the Orifice of which at D, the tinged Water is poured, and fills up the Space B C, compreſſing the *Air* in the Globe A, in which, when the

the *Air* grows more hot, it expands it ſelf and takes up the greater room by preſſing the *Water* in the Tube upwards to D; and when the *Air* is cooled, it is again condenſed, and the Water falls down; ſo that the riſing of the Water denotes its Heat, and the falling the Coldneſs of the Air, contrary to what is done in the firſt Sort.

Plate 6. *Fig.* 12.] 3. The third Sort is in this Faſhion. Thro' the narrow Neck of a Glaſs *Bottle* filled with Water, is put a long Tube open at both Ends, the lower End of which is immerſed below the Water; after having fixed the Tube with Cement, ſo that there can be no Communication between the external Air and that in the *Phial*, Air is blown ſtrongly thro' the Tube, by which the Air in the *Phial* is compreſſed; and therefore it will preſs the Water up to D; and if the Air always continues in the ſame Tenor as to Heat and Cold, the Water would always continue in the ſame Station; but when the Air in the *Phial* grows hotter, it will endeavour to expand it ſelf, and preſs more ſtrongly on the Surface of the Water, and raiſe it higher in the Tube.

In theſe Sorts of *Thermometers*, and all others which have any Communication with the external

Air,

Air, the Liquor will not only be raiſed or depreſſed by the Change of Air, as to Heat or Cold; but alſo to any Alteration as to Gravity or Levity; and conſequently the Temperature of the Air as to Heat and Cold may remain, when nevertheleſs the Height of the Water may be conſiderably altered.

Plate 6. *Fig*. 5.] 4. This Sort of *THERMOSCOPE* is not liable to the ſame Inconvenience. It is a long Tube with a Glaſs Ball at the End of it, which being filled with high and rectified *Spirits of Wine* half up to D, the remaining empty Part C is conſiderably heated, that the *Air* may be expelled; after this the top of the Tube is to be immediately Sealed *Hermetically*, ſo that the *Air* may not re-enter the Tube; then the Rarefaction and Condenſation of the *Spirits of Wine*, by which it riſes or falls in the Tube, according to the Degrees of Heat or Cold, ſhew the Temperature of the *Air* as to Heat and Cold.

Plate 6. *Fig*. 14.] 5. Another Sort of *Thermoſcope* is thus contrived. A and B are two Cylindrical Glaſs Veſſels joined to the *Recurve Tube* DGF; the upper Part of the Veſſel A is void of *Air*,

Air, and the rest is filled with ☿, as in the *Torricellian Experiment*, and the ☿ rises half way in the Vessel B. On the Surface of the ☿, there is put in a Tube some tinged Liquor, or rather *Oil of Tartar per Deliquium*, which will not Freeze, which reaches up to D, to the End of the Tube B K; a Glass Globe C full of *Air* is Sealed on *Hermetically*, to prevent Communication with the external *Air*. In this *Thermometer*, when by the Cold in the ambient Air, the Air C is cooled and condensed; the ☿ will by its own Weight subside in A, and rise higher in B, and consequently impel the Liquors up into the Tube B K; and if the *Basis* of the Cylindrical Vessel A and B be ten Times greater than the *Basis* of the Tube B K; when the ☿ falls one Inch in A, or rises one in B, the Liquor will rise ten Inches in the Tube B K; also if the Air be heated in C, and rarified, it will by expanding it self, make the ☿ descend in B, and rise in A; so that the smallest Variations as to Heat and Cold are thus shewn by the Ascent and Descent of the Liquor in the Tube B K.

To measure the Moisture and Dryness of the Air, we use an Instrument called an *HYDROMETER* of which there are two or three Sorts.

Plate

Plate 4. *Fig.* 11.] 1. The Firſt is made by a *Force-Balance*, in one of the Scales of which is put a Piece of Spunge, and in the other a Weight to Counterpoiſe it; the Spunge in damp Weather imbibes the Moiſture and grows heavier. In dry Weather the Moiſture being exhaled, the Spunge becomes lighter: And ſo by the Motions of the Examen we find the Alteration of the *Air*, in reſpect of its Humidity. To make the Variations the more ſenſible, the Examen of the *Balance* is made very long, which paſſes on a circular *Arch* of *Braſs* divided into Degrees, marked 1, 2, 3, *&c.* According as the End of the Examen is at any of theſe Degrees, ſo we judge of the Weather.

Plate 6. *Fig.* 2.] 2. Another Sort is contrived after this manner. To a Rope or Cat's-Gut, a Cylindrical Weight is tied; in damp Weather the Rope by twiſting it ſelf will contract and pull up the Weight, and in fair Weather lets it ſink farther down. To make the Variations more ſenſible, the Cylindrical Weight being about fifteen or ſixteen Inches round, is divided into thirty or forty equal Parts, marked 1, 2, 3, *&c.* To prevent its being injured a Glaſs is put over it, thro' which

the String paſſes at A; this Glaſs is covered with Brown or Blew Paper, except one ſmall Hole, thro' which the Figure on the Side of the Weight may be ſeen. Now the twiſting or untwiſting of the Rope, according to the Variation of the Moiſtneſs of the *Air*, will always preſent a new Figure to the Hole.

Plate 6. *Fig*. 17.] 3. A third Sort of *HYDROMETER* is made with the *Beard* of a wild *Oat*, or the *Husk* of a ſmall *Vetch*, which in dry Weather twiſts, and in wet Weather untwiſts. One End is faſtned to the Bottom of a *Box*, the other comes thro' an Hole in the Lid, and has an Index adapted to it, ſo that the Motion of the Hand or Index on the Top of the *Box* ſhews the Variation of the Moiſtneſs and Dryneſs of the Weather.

CATOPTRICKS.

DEFINITIONS.

1. R*AYS of Light are thoſe which are diffuſed every way in ſtrait Lines thro' the ſame Medium, and ſpread themſelves conſtantly after the ſame Tenor, as long as they continue in the ſame Medium.*

2. *A Radiant is that, from whoſe Points Rays diſperſe themſelves every way.*

3. *Diverging Rays* (Plate 7. Fig. 3.) *are thoſe which meet in a Point oppoſite to the Direction of their Motion, or thoſe Rays which ſpread themſelves after that manner, as if they had all come from one Point, whether they really came from that Point or not. As the Rays B D going from B to D, are ſaid to diverge from the Point C, whether they actually come from it or not; for tho' they ſhould come from A, they are ſaid to diverge from C, becauſe if you produce them from B till they meet in a Point oppoſite to the Direction of their Motion, that Point will be C.*

4. *Con-*

4. *Converging Rays are those which meet, or being produced, meet in a Point towards that Part whither the Direction of the Motion tends. As the Rays D B are said to Converge towards C, whether they meet in C, or after Refraction thro' the Glass E E, they go on Parallel to the Line A C D.*

5. *The Focus is that Point where the Rays meet.*

6. *Parallel Rays are those which come from a Point at a great Distance from us, and contain but a very small Angle one with another, as from the Sun.*

7. *Rays are said to Reflect, when they are turned backward in the same Medium.*

A real Focus is the Place where the Rays actually meet, as (in Fig. 5.) *the Point B where the Rays D meet, after they have past the Glass C C, and the Point A, where these converging Rays wou'd meet, if there was no Glass at C C, is called the* Imaginary Focus.

Fig. 8. Plate 7.] *In a Concave Mirror, if e be an Object, E will be the Focus of the Rays, which having diverged from the Object, and fallen upon the Concave Mirror, are by Reflection made to Converge at E.*

Plate

Plate 7. Fig. 3.] *A Concave Glaſs tranſmitting Light, has no real Focus of parallel Rays, becauſe after they have paſſed the Glaſs they diverge from one another, as the Rays A after they have paſſed the Glaſs E diverge towards D, but the Point C is called the* Vertical Focus *of the Concave Glaſs.*

8. *The Angle of Incidence, is that which is contained under the incident Ray* (Fig. 2. Plate 7.) *and the* ⊥ *to the Plane of the Point of Incidence, as A B C.*

9. *The Angle of Reflection is that which is contained under the reflected Ray, and the ſaid* ⊥ *as the Angle D B C, ſometimes A B E, and D B F, are called the* Angles of Incidence and Reflection.

THEOREME.

The Angle of Incidence *is always equal to that of* Reflection. *This is confirmed by Experience, and has been ſeveral ways Demonſtrated by Mathematicians.*

10. *Specula, or Mirrors, are thoſe which by reflecting of the Light form Images of external Radiants.*

THE-

THEOREME.

Plate 7. *Fig.* 1. *or* 4.] RAYS coming from a Point A, and falling on a plain Mirror B C, after Reflection diverge from the Point *a*, which is in the ⊥ as far behind the Glaſs, as the Radiant is before it. For becauſe A B is equal to *a* and B, and D B is common to the Triangles A B D and *a* B D, and the Angles at B are equal, the Angles A D B and *a* D B will be equal, *per* 4*th El.* 1. But by the 15 of the ſame, the Angles D A B and G D C are equal; therefore, if A D be the incident Ray, G D will be the reflected. After the ſame manner it may be ſhewn that H E is the reflected Ray of the Incident A E and K F of A F; and therefore all the reflected Rays, if produced, will meet at *a*. If the Eye was placed at H, it would receive the Rays which come from A, and are reflected at the Surface B C, as if they had really come from *a*, and conſequently the Eye will be the ſame way affected as if it came at O, *Fig.* 4. and received the Rays coming from A; and therefore the Eye at H will ſee the Image of the Point A at *a*.

Fig. 6.

Fig. 6. *Plate* 7.] Since the Image of every Point is as far behind the Glaſs as the Point is before the Glaſs, the Image muſt be the ſame way inclined to the Glaſs as the Radiant is. So the Image of the Point A muſt be at *a*, and the Image of the Point E muſt be at *e*.

Hence it follows, that if the Glaſs lies horizontally, Objects will have their Images inverted, and Men will appear with their Heads downwards, as when we look in the Water.

What has been ſhewn of the principal Radiants, is alſo true of their Images; for they may be conſidered as Objects which ſend Rays; and therefore if there be another Glaſs to receive theſe Rays, there will be another Image formed within that Glaſs, and ſo that Image will ſtill have another Image, *&c.* From whence ariſes the Multiplication of Images by the help of two or three plain Looking-Glaſſes.

Plate 7. *Fig*. 7.] Suppoſe two Looking-Glaſſes B C E F, let the Radiant be A, whoſe Image by the Glaſs B C is *a*; this Image being conſidered as a Radiant, will ſend Rays to the Glaſs E F at *a*, and this Image will likewiſe have its Image in the Glaſs B C at G, and ſo you may multiply Images

as

as far as you please. If G D H E K F (*Fig.* 4.) be incident *Rays*, their reflected *Rays* will be D A, E A, F A, *i. e.* if *Rays* be converging to the Point *a*, there to form an Image; and there be interposed a plain Speculum B, they will reflect to the Point A and Form an Image there. Experience answers to this exactly.

Fig. 9.] Take common *Reading* or *Burning Glass* E, and put the Radiant at A. Let the Place of the Image to be formed be *a*, put a *Looking-Glass* at B C, and a Man's Eye at O will see the Image at *a* in the Air between him and the Glass; for by the *Burning-Glass* the Rays coming from a Point in the Radiant A are made to Converge to *a* correspondent Point in the Image *a*; but by the *Looking-Glass* they are intercepted and reflected, therefore they will be turned another way, and those that went from one Point at A will meet with another correspondent to it at *a*, where they will form an Image.

In Concave Spherical Mirrors the Image of any Point is always in a Line passing thro' that Point and the Center.

Plate 7. *Fig.* 10.] Thus the Image of the Point E will be at *e*, the Image of F at *f*, and the Image of G at *g*. Hence

Hence it follows, that if the Image be in the Air before, it will appear inverted. The Reaſon why the Image is formed, is, becauſe all the *Rays* which come from the Point E, and falling near the Vertex of the Mirror, reflect ſo, that they will meet at *e*, whence they diverge, forming at *e* the Image of the Point E. After the ſame manner thoſe which come from F after Reflection meet again at *f*, and there form the Image of F.

If the Radiant approaches the Glaſs, the Image will recede from the Glaſs, and at the Center of the Sphere they will both meet.

If the Radiant approaches ſtill nearer, the Image will go out beyond the Center; and when the Radiant comes to be at the diſtance of a quarter of the Diameter from the Vertex, the Image will be out at an infinite diſtance. When the Radiant comes nearer to the Glaſs than a quarter of the Diameter, the Image appears behind the Glaſs, and erected. If the Mirror be Convex, the Image of an external Radiant is always behind the Glaſs.

Plate 7. *Fig.* 8.] The Magnitude of the Image may be known from this; that it always appears under the ſame Angle from the Vertex of

the Speculum that the Radiant does, and consequently they will have the same Proportion one to another as their Distances from the Vertex have; and therefore if the Radiant be farther off than the Distance from the Glass, it will be bigger than the Image, if at the same Distance at the Center they are equal; if the Image is farther off than the Radiant from the Glass, it will appear bigger than the Radiant. See the Figure where E may be the Radiant, and *e* the Image; or *e* the Radiant and E the Image.

N. B. *The Focus or Point where the Image is formed, is the middle Point between the Vertex and Center of the Speculum; in all these Cases where the Radiant is supported at an infinite Distance, as the Sun, and the Rays sent from it are reckoned as Parallel.*

DIOP.

DIOPTRICKS.

WHEN a *Ray* of Light comes out of one Medium into another, it changeth its Direction. This changing of the Direction is what we call *Refraction*.

Plate 7. *Fig.* 12.] The Angle of *Refraction* is comprehended under the refracted Ray, and a ⊥ drawn to the Surface of the refracting Medium, at the Point where the incident Ray falls on the same Medium as the Angle H D K. If the Ray of Light goes into a thicker Medium, it comes nearer to a ⊥; if into a thinner, then it recedes from the ⊥.

Fig. 11.] There are several ways to shew this by Experience. *V. G.* Take a *Bason*, into which put a Piece of Money at A, and then recede so far back, that the Sides of the *Bason* may intercept the Sight, so that the Light cannot come in a strait Line from A to the Eye at D; if Water be afterwards poured in, the Money will be seen; for the Ray A B when it comes to the Surface of the

Air at B, changeth its Direction, and goes off in D B, and so enters the Eye.

Fig. 12. *Plate* 7.] Suppose the Medium E C to be Air, H K Glass or Water, and A B the Surface of the Medium H K. Let E D be a Ray of Light, entering the Medium at D, as the Angle E D C is the Angle of Incidence, so is H D K the refracted Angle, and the Sides of these Angles have always a certain determinate Proportion to one another; and if you take small Angles, they themselves are always in this Proportion. If E C be Air, and H K Glass, the Angle E D C is to H D K, as 3 to 2. If E C be Air and H K Water, the Proportion between the Angles E D C and H D K is as 4 to 3.

Fig. 13.] To shew Refraction more plainly, take a common *Burning-Glass*, and cover it with Paper, in which let there be two Holes, thro' which the Light is to pass at B and C, then put a Candle at A; the Light passed thro' without bending the Rays coming thro' the Holes B and C, ought to diverge farther and farther from one another; but we find that if the Light be received on a Piece of Paper, the Rays converge one to another; when the Paper is at I, the Light falls at G K;

when

when it's removed farther, the Rays fall at D E nearer one another, and when the Paper is removed to F, there the two Lights coincide and then diverge again.

Plate 8. *Fig*. 4.] Suppose G H Water, I A E Air, the Rays coming out of Water into Air are refracted, so that those which came from the Point E, seem after Refraction as if they had come from C, and enter the Eye at I A, as if they had all come from that Point. So that C E is a quarter of B E.

Fig. 3. *Plate* 8.] Hence when we look on an Object in Water, it appears a quarter nearer the Surface than it is; and on the same Account an Oar in the Water will appear bent, for the Point A will appear higher, *viz*. at B, and the Point C at D; so that the Oar in the Water instead of being seen in the Position F C A, will be seen in that of F D B.

Plate 10. *Fig*. 6.] If the Object A be seen thro' the Prism G H, by the Eye at D, it will appear as if it was at C; for the Rays falling from A obliquely upon the Surface of the Prism at H, are refracted towards the ⊥ E (because they go from Air into Glass) and would go on still in the

the *Direction* H G if they continued to move in Glaſs, but emerging out of Glaſs into Air, they are refracted from the ⊥ to F, and going on in the Line D G, enter the Eye as if they came directly from C.

If the ſame Object be ſeen thro' a Medium which terminated by many plain different Surfaces, it will appear to be multiplied into as many as there are Surfaces, for thro' every Surface the Object is ſeen in a different Place; and conſequently as many Surfaces as there are, ſo many diſtinct Objects will appear. The Rays which come from the Objects thro' theſe different Surfaces of the Glaſs forming the Images therein on different Parts of the Retina.

A *Lens* is a Glaſs which is terminated by two Spherical, or one Plain and one Spherical Surface.

And it is Convex on both Sides, or Convex on one Side, and Flat on the other.

Concave on both Sides, or Concave on one Side, and Flat on the other.

Or a *Meniſcus*, that is, Concave on one Side, and Convex on the other.

Plate 10. *Fig.* 5.] When Rays diverge from any Point of an Object, and ſpread themſelves every

very way, if then you expoſe a *Convex-Lens* to theſe Rays, they will form a Cone, whoſe Vertex is at the Point of Divergence, and Baſe at the *Lens*; as the Rays which diverge from A, and fall on the Glaſs C D; when theſe Rays paſs thro' the Glaſs they are all refracted (except that which falls at E on the Middle of the Glaſs) and meeting again at the Point B, form another *Cone* whoſe *Baſe* is the Glaſs C D (on the other Side) and Vertex at B: This *Cone* together with the other *Cone* is called a *Pencil of Rays*, and A E D is the *Axis* of the Pencil, or a Line drawn from the Point of Divergence on the Side of the Glaſs, to the Point of Divergence on the other. There are as many Pencils of Rays thro' a Glaſs as there are viſible Points in the Object, and tho' the *Axis* of the oblique Pencils ſuffer ſome Refraction in paſſing obliquely thro' the *Lens*, yet they are not to be looked upon as refracted, becauſe after they have paſſed the Glaſs, they go on in a Line H, *Fig*. 5. to the Line in which they moved before they entered it, and the thinner the *Glaſs* is, the more inſenſible is that *Refraction*.

Plate 8. *Fig*. 1.] *A a*, *B b*, *C c*, repreſent three Pencils of Rays paſſing thro' a double *Con-*

vex-

vex-Glaſs. When the Object A B C by means of a double *Convex-Glaſs* has its Image projected at at *b c a*; the *Angles* which the *Axis* of theſe Pencils that come from the Extremities of the Object make with the Middle of the *Glaſs*, determine the Magnitude of that Image; and the Place where the Pencils of Rays terminate on theſe *Axes*, is called the *Diſtinct Baſe*, becauſe there only is the moſt *Diſtinct Image* of the Object projected.

Plate 8. *Fig.* 1.] By the former *Experiment* it was ſhewn, that the Light which comes from a certain Point in the Candle, placed at a due Diſtance from the *Glaſs* or *Lens*, was made by Refraction to converge and meet at a Point; therefore if there be an Object placed before the *Glaſs* at A B C, all the Rays which come from the Point A will after Refraction be made to converge at the Point *a*, and all the Rays which come from B will after Refraction meet at *b*, and all the Rays which come from C will be refracted to *c*; and if the Eye be at *a*, it will receive the Rays diverging from the Points *a b c*, the ſame way as if it had received the Rays directly coming from the principal Radiants A B C; and therefore the Image will be formed at *a b c* and inverted.

If

If a piece of Paper be placed at *a b c*, the Rays will thence be reflected by the Paper, and will Point on the Paper the *Image* of the Radiant.

The *Image* and the Radiant have always the same Proportion the one to the other, that their Distances from the *Lens* have; and therefore if the *Image* be farther from the *Lens* than the Radiant is, it will be bigger than the Radiant is; if nearer it will be less. If the Radiant at A B C be brought nearer to the *Lens*, the *Image* will recede farther from it; and it may be brought to such a determinate Distance, as to cast the *Image* as far from the Glass as may be required to magnifie it to any given Proportion. If the Glass be equally Convex on both Sides, and the Radiant placed at a Semidiameter's distance from the *Lens*, the *Image* is cast out at an infinite Distance; and if the Radiant be placed at an infinite Distance, the *Image* is at a Semidiameter's distance from the *Lens*.

If the *Sun* be the Radiant which is at an infinite *Distance*, and the *Glass* be sufficiently broad; in the Place of the *Image* there will be a Flame, which will burn very intensely, because all the Rays which come directly from the *Sun*, and fall on the broad *Lens*, are by Refraction brought into a small Space to form the *Image*.

 Plate

Plate 8. *Fig.* 6.] If at the Place of the *Sun*'s *Image* (which is ſometimes called the *Focus* of parallel Rays, or ſometimes ſimply the *Focus*) there be placed a Lucid Body, as a Candle or Lamp, the Rays, after Refraction thro' the *Lens*, will go out parallel, and not diverge from one another; and the Light not ſpreading, will continue in the ſame Intenſeneſs at all *Diſtances*, and conſequently it will illuminate Objects at a diſtance. On this Principle *Convex-Lanthorns* are made.

If the Radiant be nearer the *Lens* than the *Focus* of parallel Rays, the *Image* will not be ſeen on the other Side of the *Lens*, but on the ſame Side that the Radiant is, only farther of, and not inverted, but erect.

Fig. 5.] Suppoſe A B C a Radiant nearer to the *Lens* than the *Focus* of parallel Rays, all the Rays which come from the Point, A, will enter the Eye at E, as if they had come from the Point *a*; and all the Rays which come from B and C will ſeem to have diverged at firſt from *b* and *c*; and ſo the Eye will ſee the Object not at A B C, but at *a b c*; and becauſe the Angle D E D is the ſame with *a E c*, the *Object* will be ſeen magnified, *a b c* being greater than A B C.

If

If a *Room* be darkned, and only one Hole made in the Window to let in the *Rays* which come from external *Objects*, and in the Hole there be placed a *Convex Lens*, this *Lens* will form the *Images* of all external *Objects* that are before it; and if at a diſtance there be put a Piece of white Paper, the *Images* will be received on it, and they will all appear inverted: The Reaſon of which follows plainly from the former Principles; for all the *Rays* which come from any one Point of the *Object*, will by Refraction be made to meet at one Point on the Paper, and thence they will be reflected again; and the ſame thing is true of every other Point: So that the *Image* of every Point thus put together on the Paper will ſhew the *Image* of the radiant Object in the ſame Colour the Object is of, becauſe every *Image* is formed by the very ſame Rays, and of the very ſame Affection as to Colour, as they which come from the Objects are. The Objects being much farther from the *Lens* than the *Images* are, theſe muſt be much leſs, and the nearer the Object is to the *Lens*, the *Image* will be the farther from it, and appear the bigger.

If the Object move, the *Image* will alſo ſeem to move; provided it do not move directly towards the *Lens*. By this Principle the Proſpect of Places may be taken.

Plate 7. *Fig*. 14.] The Appearances of the *Magick Lanthorn* differ but little from thoſe of the dark Chamber. The *Lanthorn* has two *Convex-Glaſſes* at A and B B, and a *Lamp* burning; at F there is a Slit made to hold a long Piece of Wood D C, in which are cut ſeveral round Holes to hold the *Pictures* which are of painted *Glaſs*; and the Flame of the Candle or Lamp E being great, a conſiderable Quantity of Light falls on the *Pictures*, and paſſing thro' the two Lens's, will form the Images of theſe *Pictures* on the oppoſite Wall: The *Pictures* being much nearer to the *Lens* than their *Images* on the Wall, the *Images* will be prodigiouſly larger than the *Pictures*, according as the Wall is diſtant. If by pulling out the Tube in which the *Lens* B is fixed, you make the Diſtance from the *Pictures* greater, the Diſtance of the *Images* will be leſs, and conſequently the *Images* themſelves will be leſs in proportion.

Plate

Plate 8. *Fig.* 13.] A *Concave Lens* forms the *Image* on the ſame Side that the *Radiant* is, but much leſs and nearer it. For if the *Object* B A be put before the *Lens* E F, it will be ſeen by the *Eye* at C, in the Poſition *a b*, and by conſequence leſs than the *Object*; for the *Ray* A E falling on the *Lens* at E, is refracted into *g* E, and comes nearer to the ⊥, and the *Ray* E *g* coming on the Convex Surface of the *Air* at *g*, will be refracted into *g c* and recede from the ⊥: So that the *Rays* A B will enter the *Eye* at C or *c*, as if it had come directly from *a*, and not from A. So that the *Eye* being at C, and receiving the *Rays* coming from A and B, will be the ſame way affected as if they came from *a* and B. After the ſame manner the *Rays* which come from B will enter the *Eye* at C, as if they had come from *b*, ſo that the *Eye* will ſee the Object B A at B *a* nearer to it, and alſo much leſs than it really is.

Plate 8. *Fig.* 8.] The *Eye* is a *Lens* contrived by GOD to project the *Images* of external Objects on the *Retina*; and then it is that we ſee diſtinctly, when thoſe *Images* are diſtinctly painted on the *Retina*. Immediately under the firſt Coat of the *Eye*, which is called the *Tunica Cornea*, A

B,

B, there's an Humour of the ſame Conſiſtence with Water, and is called the Aqueous Humour E F. In the Middle of this there ſwims another *Membrane*, called the *Uvea* C D, which is opaque, and lets no Light paſs thro' it, but as perforated at C D, and the ſmall Hole is called the *Pupilla*; ſo that all the Light which forms the *Image* muſt paſs thro' that Hole. Next to the watery Humour is a conſiſtent Globe, which is called the Chriſtalline Humour K, and behind this is placed the vitreous Humour H G, which is not conſiſtent as the Chriſtalline, but yet is firmer than the Aqueous. Behind the vitreous Humour lies the *Retina*, which ariſes from the Inſertion of the Optick Nerve at L, and it is ſuppoſed to conſiſt of an infinite Number of ſmall Nerves, ſtanding ⊥ by, on the Concave Surface of the *Eye*, on which the *Images* of external Objects are painted. The Figure of the *Eye* is Spherical, being the only Figure which can turn every way in the Hole it fills up.

Now becauſe thoſe *Rays* only which come from any ſingle Point of an Object, and fall on the Middle of the *Eye* at M, are united at one Point on the *Retina*, thoſe which fall at A and B obliquely, not being exactly united with the reſt, at

that

that Point, therefore the *Eye* is furniſhed with the *Uvea*, an opaque Coat, which intercepts all thoſe *Rays* which fall obliquely on the *Eye*.

The *Pupilla* or Hole in this Coat, has Power to dilate or contract it ſelf, to let more or leſs Light paſs thro' it, and in the Day time it is but ſmall; for too much Light from the Sun would hurt the *Eye*: In the Night time it grows wider, to let in all the Light it can to affect the *Retina*; and this is the Reaſon why at Twilight Things appear bigger than they are, for the *Pupilla* being very wide, a great many *Rays* come on the *Retina*, which fall on the Corner very obliquely, and therefore will not all be united in one Point on the *Retina*, but take ſome Space on it, and ſo the *Image* of the whole will be much greater than it ought to be. 'Tis on the ſame Account that a Candle, in the Night time, ſeen at a Diſtance, appears much greater than it ought to do, and the ſame is true of the fixed Stars, for they appear much leſs if we look at them thro' a ſmall Hole in a Paper.

To make all this plain, take two Tin Tubes made to go one within the other, ſo that you might make them longer or ſhorter as you pleaſe;
if

if at one End of theſe Tubes was put a *Lens*, and at the other faſtened a piece of oiled Paper, or any thin *Membrane* of an Animal to repreſent the *Retina*, and the End where the *Lens* is put, be covered with a Lid, in which muſt be made a ſmall Hole to repreſent the *Pupilla*; then if you draw the *Retina* backwards or forwards, you will at a certain Diſtance ſee the *Images* of external Objects painted on it in their true Colours, as in the dark Chamber, or Magick Lanthorn.

Since then the *Eye* is a *Lens* which projects the *Images* of external Objects on the *Retina*, if the *Eye* ſhould keep always the ſame Figure, and the *Retina* the ſame Diſtance behind it, there would be but one certain and determinate Diſtance at which it would ſee Objects diſtinctly; V G. If the *Retina* were juſt at the Diſtance of the *Focus* of *Parallel Rays* from the *Cornea*, no Objects would have their *Images* diſtinctly projected on the *Retina* but thoſe which are at a good Diſtance from it, ſo long as the *Eye* kept that Figure; but if the *Eye* were of ſuch a Figure, as to caſt the *Images* of near Objects on the *Retina*; if the Objects were farther removed, the Images would not fall on the *Retina*, but between the *Cornea* and it. If then

then the *Eye* kept one and the ſame Figure always, there would be no diſtinct Viſion, but when *Objects* are at one determinate Diſtance from the *Eye*, which would be very inconvenient for *Animals*: And therefore to remedy this, the *Eye* has the Power of changing its Figure, whereby the *Cornea* is ſometimes part of the Surface of a larger Sphere, ſometimes of a leſſer, and it is on this Account that the *Eye* is made to conſiſt of various and flexible Humours and Parts, the moſt moveable of all which is the watery Humour, lying immediately under the *Cornea*, next to which is the Chriſtalline of the firmeſt Conſiſtence; the Chriſtalline is cloſely embraced by the *Ligamentum Ciliare*, by which it is ſuſpended, and the Fibres of the Ligament by their Contraction or Dilatation bring the Chriſtalline backwards or forwards. When the Chriſtalline is brought forwards, it forwards the aqueous Humour, and makes the *Eye* more protuberant, or the Segment of a leſſer Sphere: On the contrary, when the Chriſtalline is brought back, the aqueous Humour returns alſo, and the *Eye* becoms more flat, or the Segment of a larger Sphere; ſo that by the Motion of the Chriſtalline the *Cornea* is made more or leſs convex, the

greateſt Refraction being made on the *Cornea*. 'Tis by this Mobility or Changeableneſs of the *Eye* that we are made to ſee *Objects* at different Diſtances from us.

If the *Objects* are at a Diſtance, the *Eye* that looks at them grows flatter, if they are near us, the *Eye* grows more convex: Now if the *Eye* could apply it ſelf to ſee *Objects* at all Diſtances from us, we could always ſee every *Object* diſtinctly, and near *Objects* would be brought ſo near the *Eye*, that we could ſee them magnified in any Proportion we pleaſed. For we eſtimate the Magnitude of Objects ſeen with one *Eye* by the Angle under which they appear: Thus the Object A B (*Plate* 8. *Fig*. 10.) appearing under the Angle A E B, its Image takes up the Space *a b* on the *Retina*, but the Object C D appearing only under the Angle C E D, its Image takes up only the Space *c d* on the *Retina*.

One and the ſame Object at different *Diſtances* from the *Retina*, will appear under very different Angles. Suppoſe A B (*Fig*. 11.) the Object, and the *Eye* at *c*, the Angle under which the Object appears, is the Angle A C B, if the ſame Object be removed to *a b*, the Angle under which it

appears

appears is the *Angle a* C *b* if it be brought to *a b*, the *Angle* at the *Eye* is *a* C *b*, so that the *Angle* will still be greater the nearer the Object comes to the *Eye*.

Fig. 14.] Suppose then a small Object A B, which of the ordinary *Distance* at which the *Eye* lies, appears under the *Angle* A C B, which is so very small that the *Eye* can't perceive the Parts of the Object distinctly; if then the *Eye* were brought Ten or a Hundred times nearer V. G. to D, and if it could form it self to see distinctly at all *Distances*, it would appear to the *Eye* under the *Angle* A D B, Ten or a Hundred times bigger than A C B, and consequently the Object will appear Ten or a Hundred times magnified: But then tho' the *Eye* consisting of flexible Parts, can change its Figure so as to lie at several *Distances*, yet this Mutability of Figure consists within certain Limits, and there must be certain *Distances* in which an Object must be put to be seen distinctly; so that if the Object be put nearer the *Eye* than this determinate *Distance*, it can never be seen distinctly, the Image not falling on the *Retina*, but its Place would either be behind the *Retina*, if the Rays could go so far before they

were intercepted, or the Image will be vertical and before the *Eye* if the Object were nearer than the *Focus* of Parallel Rays, and consequently it can't be painted on the *Retina*.

If there were any solid Bodies swimming in the aqueous Humour, those can never have the Images on the *Retina*, but their Images will be vertical and before the *Eye*. This is a Demonstration that the *Muscæ Volitantes* can never be produced by Objects swimming in the aqueous Humour, as Physicians generally imagined.

Plate 8. *Fig*. 17.] Since then the Object AB may be so near the *Eye* at D, that it will be without the Limits of distinct Vision; it's plain that it can't be seen magnified to the naked Eye in any given Proportion, which it would be, could the Eye see distinctly at all *Distances*; but if before the Eye D be put a *Lens* CE, which consists of Segments of small Spheres, and the *Distance* of the Objects from the *Lens* be less than the *Focus* of the Parallel Rays, the *Lens* will form the Image of the Object AB at *ab*; that is, all the Rays which come from the Points A and B will enter the Eye as if they had come from the Points *ab*, and the Eye will see the Object at *ab*, at the *Di-*

stance

ſtance neceſſary for diſtinct Viſion, and it will appear under the *Angle* A D B, or *a* D *b*, which is the very ſame that it would have been under to the naked Eye at D. If the Object were placed at the *Focus* of Parallel Rays, then all the Rays which come from the Point A after Refraction thro' the *Lens*, would go Parallel and enter the Eye as if they had come from an infinite *Diſtance*, ſo the Eye would ſee the Point A in the Line A *a* produced in *Infinitum*. The ſame thing is true of the Point B, and the Object would be ſeen at an infinite *Diſtance* under the *Angle a* D B, which is the very ſame under which it would be ſeen by the naked Eye, if it could ſee it at D diſtinctly.

Fig. 16. *Plate* 8.] Suppoſe an Object A B, which to the Eye at C the ordinary *Diſtance* for diſtinct Viſion appears, under the ſmall *Angle* A C B, if then I would ſee this Object an Hundred times magnified, I take a ſmall *Lens* whoſe *Focal Diſtance* for Parallel Rays is an Hundred times leſs than A C or B C, and put the *Lens* at G, ſo that the *Diſtance* of the *Lens* from the Object may be a Hundred times leſs than the *Diſtance* of the Eye at C from the Object: If then I bring my Eye to D to the *Lens*, I ſhall ſee the Object thro' the

the *Lens* under the *Angle* A D B, which is a Hundred times greater than A C B, and the Eye will ſee the Object thus magnified diſtinctly, becauſe it ſees at a greater *Diſtance* from the Eye; for moſt Mens Eyes are framed to ſee Objects at a good *Diſtance* from the Eye diſtinctly.

Fig. 15. *Plate* 8.] If there were an Object A B and a *Lens* E, whoſe *Focal Diſtance* is F E, that Object would appear by the *Lens* under the *Angle* A E B: If there were a *Lens* whoſe *Focal Diſtance* is D F, the *Angle* under which the Object will appear will be A D B, greater than A E B; if there were another *Lens* at C, whoſe *Focal Diſtance* is C F, the *Angle* under which the Object would appear thro' this *Lens* is A C B, which is ſtill greater than A D B. The leſs then the *Focal Diſtance* of Parallel Rays of any *Lens* is, the more 'twill magnify the Object. And if the *Lens* be equally convex on both Surfaces, the *Focal Diſtance* for Parallel Rays is a *Semidiameter's Diſtance* from the *Lens*; the leſs then the *Semidiameter* of the Sphere is, of whoſe Segment the *Lens* is made, the more it will magnify the Object; and the whole Art of magnifying Objects by ſingle *Microſcopes*, is to grind Glaſſes exactly of Portions

of

of very ſmall Spheres. *Lewenhoeck* and *Melon* pretended to grind Glaſſes whoſe *Focal Diſtance* not much exceed the hundreth Part of an Inch. I have heard of ſome that are leſs, and if they were let fall on Paper, there would be need of another *Microſcope* to find them with.

To know how much any of theſe ſingle *Microſcopes* magnify; take a ſmall piece of Paper, ſuppoſe 'tis of an Inch *Diameter*, and paſte it on a Wall; then take a *Microſcope* and put any ſmall *Object* at the *Focus* of Parallel Rays from it; then recede ſo far from the Wall, till the Paper on it appears of the ſame Bigneſs with the *Object* ſeen thro' the *Microſcope*; then conſider what Proportion the *Diſtance* of your Eye from the Paper on the Wall bears to the *Diſtance* of the *Object* from the *Microſcope*, and in that Proportion the *Object* will be magnified, or appear greater than it would do were it placed at the ſame *Diſtance* from the Eye with the Paper on the Wall.

We may perform this more eaſily thus. Take a round piece of Paper of about two or three Inches *Diameter*, and dye it black with Ink, then paſte it on a Pane of Glaſs in the Window and recede ſo far from it, till looking thro' the *Microſcope* with one

one Eye on the *Object*, and with the other on the Paper, you perceive them both of the ſame Bigneſs, or the one exactly to cover the other, the Proportion between the Paper and the *Object* will be exactly as the *Diſtance* of the *Object* from the *Microſcope* to that of the Eye from the Paper; and conſequently when the *Object* appears of the ſame bigneſs with the Paper, it is magnified in that Proportion.

Tho' moſt Mens Eyes have ſuch a Flexibility and Changeableneſs of Figure, that they can't only ſee *Objects* at a great *Diſtance*, if they appear under any ſenſible *Angle*, but alſo thoſe that are within two or three, or one Foot of their Eye, yet there are ſeveral whoſe Limits of *Diſtance* for diſtinct *Objects* as to their Viſion, are much leſs. V. G. Some can't ſee *Objects* but when they are very near them, or cloſe to their Eye, which being very convex, or the Segment of a ſmall Sphere, will unite the Rays of *Objects* at a *Diſtance* before they come to the *Retina*. They who have this Fault in their Sight are called *Myopes*.

On the contrary, there are others whoſe Eyes are very flat, or Segments of large Spheres, who can't ſee unleſs the *Objects* be at a good *Diſtance* from them,

them, and the Rays which come from one Point to fall into the Eye are *quam proxime* Parallel — Because old Men have generally their Eyes very flat, so that they can't see but at a Distance; therefore those who are troubled with this Fault, are called *Presbytæ*: Both their Faults of Vision may be helpt by *Lens*'s; for those who are Short-sighted, and can't see any Object but what is very near them, by looking thro' a Concave Lens, will see distinctly Objects, which at the same Distance without the Lens, they could not see but very confusedly.

Plate 8. *Fig.* 9.] Suppose the Object A B C, and the Eye of a *Myopes* at *E*, the Object being without the Limits of distinct Vision, will be seen confusedly by the Eye at E; but if you put in the Concave-Lens at G between the Object and the Eye all the Rays which come from it will enter the Eye as if they had come from *a*, which is much nearer to the Eye, and within the Limit of distinct Vision; the same may be said of B and C from this *Experiment*; therefore it's plain that by the help of such a Lens, the Eye of a *Myops* will see distinctly the Object A B C tho' much less than if it had seen it without the Lens.

Plate 8. *Fig.* 12.] As a Concave-Lens makes Short-sighted People see more distinctly; so also the Convex-Lens helps off the Sight of a *Presbyta*; for suppose A B an Object, and the Eye at C, this Object is so near the Eye that it can't be seen distinctly by it. If therefore there be a Concave-Lens put at E, so that the Object may be within the *Focus* of Parallel Rays, the *Eye* will see the Object A B at *a b*, at a farther Distance, and within the Limits of distinct Vision; and it will see the Object take up the Space *a b* which is greater than A B, and therefore it will see it magnified; whereas an *Object* seen thro' a *Lens* fit for a *Myops* does always appear less.

Double Microscopes are those which consist of 2, 3, or 4 Lens's that are designed to magnifie the Object.

Plate 9. *Fig.* 1.] The first sort is made after this manner. C is a Lens of a small Sphere, before which the Object A B is placed at such a Distance, that the Image made by the Lens C may be cast out at a great Distance on the other Side, *viz.* at *a b*, so that if *a b* be 10 or 100 times farther from C than A B is, it will be 10 or 100 times greater than A B. D E is another Lens which

which is larger and put ſo near the *Image a b*, that *a b* will be either in its *Focus* of parallel *Rays*, or ſomewhat nearer ; ſo that the *Image* of the *Image a b*, made by the *Lens* D E, may be caſt out at a diſtance, fit for diſtinct Viſion. Now if the *Eye* be applied at G, it will ſee the the *Object* under the *Angle*, equal to the *Angle* E *f* D, and conſequently magnified, and at a diſtance fit for diſtinct Viſion.

Plate 9. *Fig*. 2.] Moſt of the double *Microſcopes* now in uſe have three *Glaſſes*, and are made thus. C is the *Object Glaſs*, which is the Portion of a ſmall *Sphere* ; A B is the *Object* ſomething farther than the *Focus* of parallel *Rays* ; ſo that the *Image* may be caſt out, and fill the Space *a b* 10 or 100 times greater than A B. D E is another *Lens* or *Segment* of a larger *Sphere* placed at a little diſtance from *a b* ; to this join the Glaſs G H, which is the *Segment* of a *Sphere* ſomewhat leſs than D E : So that the Diſtance between the *Glaſſes* G H and D E, may be leſs than the Diſtance of the *Focus* of parallel *Rays* of the *Glaſs* G H, and that the *Rays* which come from the *Image a b*, may paſs the two *Glaſſes*, and after Refraction enter the *Eye* at L. So that all thoſe

Rays which come from the ſame Point of the *Image a b*, may enter the *Eye* as if they had come from an infinite Diſtance, *i. e.* the two *Glaſſes* G H and D E ought to be ſo placed, that the *Rays* which come from any one Point of the *Object a b*, may after Refraction thro' theſe two *Glaſſes* run parallel, and ſo form in the *Eye* a diſtinct *Image*; for it is plain, that in this Caſe the *Eye* will ſee the *Object* much magnified and diſtinct. By this *Microſcope* the *Eye* can perceive a greater Portion of the *Object* than by the former; becauſe the *Rays* at *b* and *a* would fall ſo obliquely on the *Glaſs* D E, that without the third *Glaſs* H G, they could not enter the *Eye*, and conſequently without that *Glaſs* the *Eye* will ſee only the middle Part of the *Object*.

As *Microſcopes* are uſed to diſcover the ſmall Parts of theſe Bodies we have near us, and put at a due Diſtance from the *Miſcroſcope*: So *Teleſcopes* are for diſcerning Bodies diſtinctly that are at great Diſtance from us; ſo that the *Rays* which come from any one Point of the *Object*, and fall on the object *Glaſs* of the *Teleſcope*, may be conceived as Parallel, and conſequently they will unite and form the *Image* as the *Focus* of parallel *Rays*.

Plate

Plate 4. *Fig.* 15.] The first and most simple Sort of *Telescope* is the *Astronomick*, for looking at the *Stars.* C D represents the object *Glass*, which is a Portion of a very large *Sphere* ; A E and B E, are two *Rays* which come from the Extremities of an Object placed at a great Distance, as the Object A B is to be supposed. All the *Rays* which come from the same Point that A E came from, will after Refraction thro' the *Lens* meet at *a*, and all the *Rays* which come from the same Point of the Object with the *Rays* B E, will after Refraction meet at the Point *b* ; so that the *Image* of the Object will be placed at *b a*, at the Distance of the *Focus* of parallel Rays, as you may see by the pricked Lines.

Suppose G F H a *Lens* of a much greater Convexity, or a *Segment* of a much larger *Sphere* ; placed so near the *Image a b*, that *a b* may be in its *Focus* of parallel Rays, that is to say, all the Rays which come from the Points *a* and *b*, may after Refraction run parallel and enter the *Eye* at L, as if they had come from a great Distance ; these *Lens*'s being thus adapted, and put in a *Tube*, the *Eye* will see distant Objects distinctly, and magnified in the Proportion that the focal *Di-*

stance

ſtance of the *Glaſs* C D, as greater than the focal *Diſtance* of G H. For firſt the *Eye* will ſee the Object diſtinctly, becauſe the Rays which come from the Points *a b*, falling on the *Eye* at L, as if they had come from a great *Diſtance*, will be exactly united in the *Retina*, and therefore a diſtinct *Image*.

2*dly*. The Object will be ſeen much greater than without the *Teleſcope*, for the Angle under which the Object is ſeen without the *Teleſcope*, is the Angle A L B, and the *Image* under the *Retina* of the *Eye* is A B; but the Angle under which the Object is ſeen with the *Teleſcope* is the Angle G L H and the *Image* made then on the *Retina* is K; and therefore as much as this latter Angle and Image are greater than the former, ſo much is the Object magnified by the *Teleſcope*.

Again, let A and B be two Rays coming from the End of an Object at an infinite *Diſtance*, whoſe *Image* is *a b*, the bigneſs of which is determined by the Angle *a* E *b*, which theſe two Rays make in paſſing thro' the object *Glaſs*, without any Refraction, becauſe they are the *Axes* of two Pencils of Rays: Let the focal Diſtance of the object *Glaſs* be E K, and that of the *Eye-Glaſs* F K, and

and A E B be the Angle under which the Object is seen without the *Telescope.* Now because the *Image* and the *Object* appear under the same *Angle* from the *Lens*, the *Angle* A E B will be equal to the *Angle a* E *b*, and consequently to the *Angle* under which the Object appears seen without the *Telescope*; but the Eye at L sees the *Image a b* under an *Angle* equal to *a* F *b*; and consequently so much greater as the *Angle a* F *b* is than *a* E *b*, so much greater will the Object appear when seen with the *Telescope* than when seen without it: But so much as E K is greater than F K, so much is the *Angle a* F *b* greater than *a* E *b*, *i. e.* the *Object* is magnified in proportion to the focal Distance of the object *Glass*, keeping the same *Eye-Glass*; and and consequently the longer the focal Distance, *i. e.* the longer the Space is, of which the *Lens* is a Portion, the more the Object will be magnified; and therefore the whole Perfection of these Sort of *Telescopes*, is to get object Glasses well ground of a long focal Distance. There are some of these *Telescopes* of 150 or 200 Feet in Length, but it is very difficult to manage and turn them as one pleases. It is plain, that the *Image a b* is inverted

ted in respect of the principal *Object*, and consequently whatever *Objects* we look at with these *Telescopes*, will appear inverted.

Plate 9. *Fig*. 4.] 2. *Galilæus*'s-*Telescope* does likewise consist of two Glasses, whereof the object Glass is Convex, and a Segment of a lesser *Sphere*. They are fixed in a *Tube* after this manner. C D is the object Glass, whose Focus of parallel Rays is at *a b*, *i. e.* the *Images* of distant Objects made by the Glass C D are at *a b*, so that K is the Focus of parallel Rays to the *Axis* of the Glass; so that if it were not for the interposition of the *Eye-Glass* G H, all the Rays parallel to the *Axis* would converge to the Point K; but then by the interposition of the Concave *Eye-Glass* G H, which is placed at such a Distance from the *Image* *a b*, that the Point K is in its Focus of parallel Rays or vertical Focus, all the Rays which before they passed thro' the Glass G H were converging to the Point K, will after Refraction on the Glass G H, run parallel to the *Axis*: The same way all the Rays which before the Refraction on the Glass G H, were converging to the Points *a b*, will after Refraction run Parallel one to another. So that the *Eye* near F will receive all the Rays which

which were going to *a b*, as if they had all come from *a b* placed at a great diſtance, and the *Eye* will ſee the *Object* under the *Angle a* F *b* which is equal to *a* F *b*; where it is to be obſerved that the *Image a b* is inverted in reſpect of *a b*, and *a b* will be erected and ſeen the ſame way that the principal *Object* A B is ſeen.

N. B. *The vertical Focus of a Concave Glaſs is that Point from which the Rays parallel to the Axis diverge, after Refraction thro' the Glaſs; as the Point C* (Plate 7. Fig. 3.) *is the vertical Focus of parallel Rays of the Glaſs E E, becauſe the Rays B D, which come from A, and before they entered the Glaſs were Parallel to the Axis A E, are by Refraction thro' the ſaid Glaſs made to diverge from the Point C, as if they had come really from that Point.*

Plate 9. *Fig.* 5.] 3. Becauſe the firſt Sort of *Teleſcopes* ſhew all *Objects* inverted, and the ſecond diſcovers but the ſmall Part of an *Object* at once; therefore a third Sort has been contrived, conſiſting of four Glaſſes, *viz.* one large *Object* Glaſs and three *Eye-Glaſſes,* placed after this manner. C D is the *Object-Glaſs,* whoſe Focus of parallel Rays is at *a b*: or which is the ſame

thing, let *a b* be the *Image* of ſome diſtant *Object*, therefore it will be inverted in reſpect of the *Object*. E F is an *Eye-Glaſs*, a *Segment* of a leſſer *Sphere*, placed ſo near the *Image a b*, that Rays which come from any one Point of it after Refraction thro' E F, may run parallel, and fall on a third Glaſs G H; thoſe parallel Rays falling on the Glaſs G H, will after Refraction converge to the Focus of parallel Rays, and form an *Image a b* inverted in reſpect of *a b*, and conſequently erected in reſpect of the principal Radiant. I K is another Glaſs placed ſo near the *Image a b*, that the Rays coming from any one Point of the *Image a b* may enter the *Eye* at L, as they had come from a Point at a great Diſtance; that is, they will after Refraction at I K run parallel, and then the *Eye* at L will ſee the Image diſtinctly erected and magnified.

OBSERVE, that *a b* is the common Focus of parallel Rays to the two Glaſſes C D and E F, and *a b* is the Focus of parallel Rays to the two Glaſſes G H and I K.

Sir

Sir ISAAC NEWTON's COLOURS.

PROPOSITION.

Lights which differ in Colour, differ also in Degrees of Refrangibility.

EXPERIMENT.

IF you apply any flat Side of a Prism to the Hole of a dark Room to receive the Rays which come from the Sun, these Rays which are different in Colour, will be separated by a different *Refraction*, and diverge from one another, (as in *Fig.* 1. *Plate* 10.) and appears distinctly in an oblong Figure on the opposite Wall: They will be refracted in this Order, *viz.* The red Rays will be refracted least,

the Orange ſomewhat more, the Yellow more than that, the Green yet more, the Blue more than the Green, and the Purple moſt of all. Now to ſhew that theſe Colours were not made by Refraction, but were originally in the Rays of the *Sun*; if you refract any one of them never ſo much with a Priſm, as for *Example*, the Purple in the firſt Figure, it will retain the ſame Colour.

If you contract theſe refracted Rays with a Burning-Glaſs, they will all converge to the *Focus* of parallel Rays, as in the ſecond Figure; where if you receive them on Paper, they will appear White: And to ſhew farther, that White is a Compoſition of all theſe *Colours*, if you intercept the blue Ray with a Piece of Paper, between the *Focus* and the Glaſs, the White at the *Focus* will appear Reddiſh; if the Reddiſh be intercepted it will appear Blueiſh. So that if one of theſe *Colours* is wanting, the White is imperfect.

Fig. 3. If you receive all the Rays on a Piece of Paper, as at L, *Figure 3d.* between the *Focus* of parallel Rays and the Glaſs, they will appear with their proper *Colours* in their right Order, and converging towards one another; but if they be received beyond the *Focus*, they will appear in their

their proper *Colours* on the Paper, and to have diverged from one another, whence their Order will be inverted, *viz.* the purple Ray will be in the Place of the Red, and the Red of the Purple.

To ſhew that the Rays which differ in *Colour*, tho' they have the ſame Incidence, are differently refracted, place a tall Piece of Wood with an Hole in it, *Fig.* 4. and a Priſm behind that Hole at a convenient Diſtance from the Window; then with it refract the ſeveral Rays one after another from the Hole in the dark Room, to the Hole in the Piece of Wood, and each of the Rays will be differently refracted on the oppoſite Wall. *Viz.* The *Reddiſh* will be leaſt refracted, and uppermoſt; the *Orange* next, underneath; the *Yellow* next, the *Green* next, the *Blue* next, and the *Purple* loweſt of all.

Thoſe *Objects* whoſe Parts are ſo diſpoſed, as to reflect any one of theſe Rays more than the reſt, and in a great meaſure to abſorbe and ſtifle the others, appear to be of that *Colour* which they moſt reflect; whence a blue *Ray* when refracted on a blue *Object*, appears much ſtronger than when it is refracted on one of a different *Colour*, and ſo of the reſt. If you look thro' a Priſm on an *Ob-*

ject

ject of any one Particular, V. G. *Green*, you will ſee it in all the other *Colours*; but the *Green* being the moſt powerful, the *Object* to the Sight of the naked *Eye* will appear altogether of that *Colour*.

Since *White* has been proved to conſiſt of all *Colours*; it follows from hence, that thoſe *Objects* which appear *White* to us, are ſuch as are diſpoſed very curiouſly to reflect all *Colours*, and the greater or leſs this Diſpoſition is in the Superficies of the *Object*, it will appear accordingly of a quite White, or elſe of a ſomewhat ſhaded Dark-brown, or ſome other intermediate *Colour*; and thoſe *Objects* which are very little, or not at all diſpoſed to reflect theſe *Rays*, will appear Black.

It may be ſo contrived by darkening a Room, and by that means letting Beams of Light fall very forcibly upon a black *Object*, that it ſhall then appear exactly White to the *Eye*.

If you expoſe two Pieces of Marble to the Sun, one White, the other Black, the Black will be hot, and retain the Heat longer; for as the White reflects, ſo the Black abſorbs the *Rays* of the Sun.

If

If an oblong Piece of Paper placed before a Window, be viewed at ſuch a Diſtance thro' a Priſm, that the Light from the Window on the Paper may make an Angle, equal to that which is made by it, *i. e.* the Light reflected from the Paper to the *Eye*, *Provided* the Paper be terminated with Sides parallel to the Priſm, and the Horizon, and diſtinguiſhed by a perpendicular tranſverſe Line into two Halves, the one of an intenſely blue *Colour*, the other intenſely Red; If the refracted Angle of the Priſm (*i. e.* its two Sides thro' which the Light paſſes to the *Eye*) be turned upwards, ſo that the Paper may ſeem to be lifted upwards by the Refraction, its blue Half will be lifted higher by the Refraction, than its red Half; but if it be turned downwards, ſo that the Paper may ſeem to be carried lower by the Refraction, its blue Half will be carried ſomething lower thereby than its red Half; becauſe in both Caſes the Light which comes from the blue Half of the Paper thro' the Priſm, to the *Eye*, is more refracted than that which comes from the red Half.

A DESCRIPTION *of the Condensing* ENGINE *with its* Apparatus.

PLATE 6.

Fig. 6. IS a *Syringe* or *Syphon* for injecting Air into the Vessel *a a a a* of *Fig.* 10.

Fig. 9. A *Mercurial-Gage* made with a Glass Tube *c c* fixed into a Piece of Wood, to know by the rising of the *Mercury* in the Vessel *a a a a.*

Fig. 7. *b b b b* represent the *Brass Hemespheres*; *g*, a *Cock* to keep the injected Air from coming out; *e e*, a hollow Piece of *Brass* thro' which the Air is injected; *d d* a *Brass* Plate to shut up the bottom of the Vessel *a a a a*; *a* one of the *Brass* Rings to hang the Weights on to draw the *Hemispheres* asunder.

Fig. 10. *k*, the other *Brass* Ring for the abovementioned purpose; *a a a a* is a Glass Vessel

ſel armed with *Braſs* Hooks at *c*, the better to keep in the Air condenſed upon the *Hemiſpheres* *b b b b* within the ſaid Glaſs. *f*, a Piece of Braſs ſcrewed to the upper Hemiſphere to ſuſtain it by help of the Pieces *e*, *e*, *g*, hanging upon the Hook *k*, whilſt the Weights in the Scale draw the lower Hemiſpheres from it, and without letting out the condenſed Air. *h*, *h*, a Board with two ſcrewed Pillars to fix the upper and lower Braſs Plates to the Braſs Veſſel, *d*, *d*, the upper Braſs Plate repreſented in *Fig.* 8. with the Collar of Leathers *f*, *f*, that the Piece *e*, *e*, of *Fig.* 7. may ſlip up and down without letting out the Air.

If the Air be exhauſted out of the Hemiſpheres (joined only by a wet *Leather*) it will require thirty Pounds to draw them aſunder; if the Denſity of the Air in the Veſſel *a a a a* be doubled by the Quantity of injected Air on the outſide of the Hemiſpheres, tho' the Air is not drawn out from between them, it will require as much Weight to draw them aſunder, as before; and double that Weight if there is a *Vacuum* between the Hemiſpheres; or if the Air is three times as denſe as at firſt. And if the Air being three times as denſe as at firſt, there be *Vacuum* between the

Hemispheres, it will require three times the Weight, namely three hundred and ninety Pound to pull them asunder.

A DESCRIPTION *of* ROWLEY'S HORARY, *or a Machine to represent the Motion of the* Moon *about the* Earth, *and the* Earth, Venus *and* Mercury *about the* Sun.

THIS *Movement* represents that Part of the *Planetary System*, according to *Copernicus*, which is circumscribed by the *Earth*'s Motion round the *Sun*, or contain'd within the Orbit that the *Earth* describes about the *Sun*.

The flat *Silver* Ring which incompasses the whole Work upon the upper Face of the *Movement*, represents the *Plane* of the *Ecliptic*, and is divided into twelve equal Parts, which are the twelve

twelve *Signs* of the *Zodiac*; each Part is again ſubdivided into thirty equal Parts, which are the *Degrees* of each *Sign*, there being three hundred and ſixty of theſe in the whole Circumference. This *Plane* of the *Ecliptic* paſſes thro' the *Sun*'s Centre, and the *Earth*'s Centre is carried round the *Sun* in the ſame *Plane*; ſo that no Body can be in a direct Line between the Centres of the *Earth* and *Sun*, unleſs that Body be in the *Plane* of the *Ecliptic*, it taking its Name from *Eclipſes*, which never happen but when the *Moon* is in or near this *Plane*.

The Places of all the *Planets* are determined by their Situations in reſpect to the *Signs* of the *Zodiac*, beginning to reckon from *Aries*, and by their being in or out of the *Plane* of the *Ecliptic*; their Diſtance in *Degrees* from the beginning of *Aries* is their *Longitude*, and their Diſtance from the *Plane* of the *Ecliptic*, either above or below it, is their *Latitude*, which is either *Northern* or *Southern*, according as the *Planet* is towards the *Northern* or *Southern* Part of the *Ecliptic*.

Each primary *Planet* moves in an Orbit, whoſe *Plane* paſſes thro' the *Sun*'s Centre; and ſince only

ly the *Earth* of all the primary *Planets* moves in the *Ecliptic*, every one of the other must consequently pass thro' the *Plane* of the *Ecliptic* at two opposite Points call'd *Nodes*.

The *Moon* moves in an Orbit, whose *Plane* passes thro' the *Earth*'s Centre. The two opposite Points where the said Orbit cuts the *Plane* of the *Ecliptic*, being the *Moon*'s *Nodes*, which are represented in the *Machine* by two *Studs*; and since the *Nodes* are always in the *Plane* of the *Ecliptic*, if the *Moon* happen to be in either of them, when they are in a *Line* with the *Sun* and *Earth*, there will be an *Eclipse*; 'twill be of the *Moon*, if the *Earth* is between the *Sun* and *Moon*, and of the *Sun*, if the *Moon* is between the *Sun* and *Earth*.

The Centre of each *Planet*'s Orbit not being in the *Sun*'s Centre, its Distance from it is called the *Excentricity*; upon this Account the *Planets* recede from, and approach towards the *Sun* at different times.

These

These Deffinitions being premised.

The large gilt *Ball* in the Centre represents the *Sun*, which you may observe to turn round upon a fix'd Axis, inclined to the *Plane* of the *Ecliptic*, in an Angle of about Eighty-two *Degrees* or eight *Degrees* distance from a Perpendicular.

The innermost small *Ball* is the Planet *Mercury*, which revolves round the *Sun* in an excentrick Orbit, with a proper *Degree* of *Inclination* to the Plane of the *Ecliptic*.

The next small *Ball* is *Venus*, commonly called the *Evening* or *Morning-Star*, which here revolves round in an Orbit of due *Inclination* and *Excentricity*.

The outermost painted *Ivory Ball* represents the *Earth*, which revolves round the *Sun* in its proper Orbit, and at the same time has a swifter *Rotation* upon a *Steel* Axis, which Axis always stands inclined to the *Plane* of the *Ecliptic* in an Angle of Sixty-six and half *Degrees*, or Twenty-three *Degrees* and half from a Perpendicular, and points the same way during the whole *Revolution*, it being always parallel to one and the same

Line;

Line; that is, if a fix'd *Star* be ſuppoſed at an immenſe Diſtance, the *Earth* ſhall always point to it, what Part ſoever of its Orbit is in the two Extremities of this Axis; namely where it goes into, and where it comes out of the Globe, repreſents the two *Poles*; the upper-moſt is the *North*, the oppoſite the *South Pole*; the other *Ball* which accompanies the *Earth* in its *Motion* round the *Sun*, and at the ſame time revolves round the *Earth*, repreſents the *Moon*, whoſe Orbit is leſs than that of the *Earth*, and has its proper *Degree* of *Inclination*.

The *Hemiſphere* of *Mercury* or *Venus*, which is turned towards the *Sun*, is always enlightened, and the oppoſite *Hemiſphere* dark, which is here repreſented by the white and black Part of the *Balls*.

It is to be obſerved of the *Moon*, that it turns once round its own Axis, whilſt it is carried round the *Earth* in its own Orbit, which is performed in Twenty-ſeven Days and eight Hours; and therefore the ſame Face is always towards the *Earth*, and it is hereby expreſſed by the white Part of the *Moon* which is always towards the *Earth* in this *Machine*; but as it is not always enlightened, there is a dark Cap which expreſſes the

ſhaded

ſhaded Part of the *Moon*, or the Part not enlightned by the Sun, and thereby is exhibited how much is enlightened of that Part of the *Moon* which we ſee from the *Earth*; that is, what *Phaſis* or Appearance the *Moon* has at any time.

Whereby is ſhewn how far any Part of the *Earth* moves round in a determinate Number of Hours.

The Circle on the *Moon's* Orbit is divided into Twenty-nine Parts and half, which repreſents the Days of the *Moon's* Age, that being the Period from New *Moon* to New *Moon*. The Number in the ſmall Circle adjoining to the *Moon's* Orbit, repreſents the Number of *Moons* or *Lunar-Months*.

The Number which appears in a ſmall Hole made on the great gilt *Plate* ſhews the Year.

From theſe Meaſures of Time you will find the *Sun* revolves upon his Axis in about 25 Days.

Mercury revolves round the *Sun* in about 87 Days, 23 Hours.

Venus revolves round the *Sun* in about 224 Days, and 18 Hours.

The *Earth* revolves about the *Sun* in 365 Days 6 Hours, and about its own Axis in 24 Hours.

And

And the Nodes of the *Moon* have a retrograde *Revolution* in her Orbit in about 18 Years and 224 Days.

All which Motions nearly agree with those in the Heavens.

So that if this *Movement* be set to any given Time, so as to represent the Situations of the *Earth*, *Sun*, and *Planets*, in respect to each other, and be afterwards set a going, it will then truly represent the Situation of the *Planets*, with regard to each other for any given Time, past or to come. Only this you must observe, that the Proportion of the Orbs of the *Planets*, in respect of the Bulks of the Bodies, and the Proportion of their Bulks to each other, could not be performed in so small a Model as this is; but that may in some Measure be remedied by making the following Allowances.

Suppose the Diameter of the *Moon's* Orb to be sixty Diameters of the *Earth*, and the Diameter of the *Earth's* Orb round the *Sun* 300 times the Diameter of the *Moon's* Orb, and the Orbs of *Venus* and *Mercury* to bear the same Proportion to the *Earth's*, as they do in this *Machine*.

Then

Then for the Bodies, imagine the *Earth* to be in Diameter a little more thẽn 3 times and half greater than the *Moon*, or in Bulk near 51 times. Suppoſe *Venus* about as large as our *Earth*, and *Mercury* about as large as the *Moon*.

And Laſtly, Suppoſe the *Sun* to be near 100 times larger in Diameter than the *Earth*, that is in Bulk one Million of times larger.

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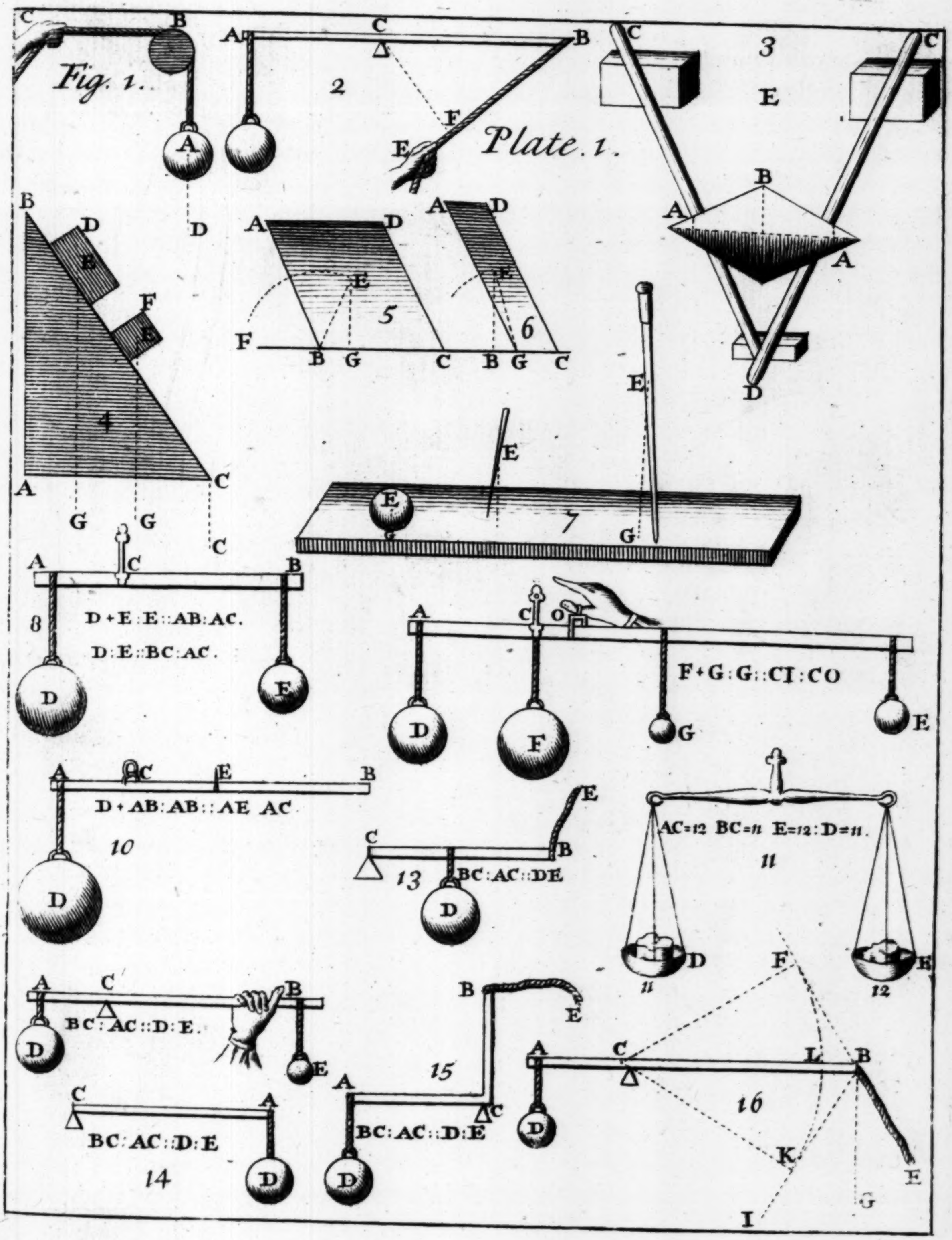

Fig. 1.
Plate. 1.
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D : E : BC : AC.
F + G : G :: CI : CO
D + AB : AB :: AE AC
AC=12 BC=11 E=12 : D=11.
BC : AC :: DE
BC : AC :: D : E.
BC : AC :: D : E
BC : AC :: D : E

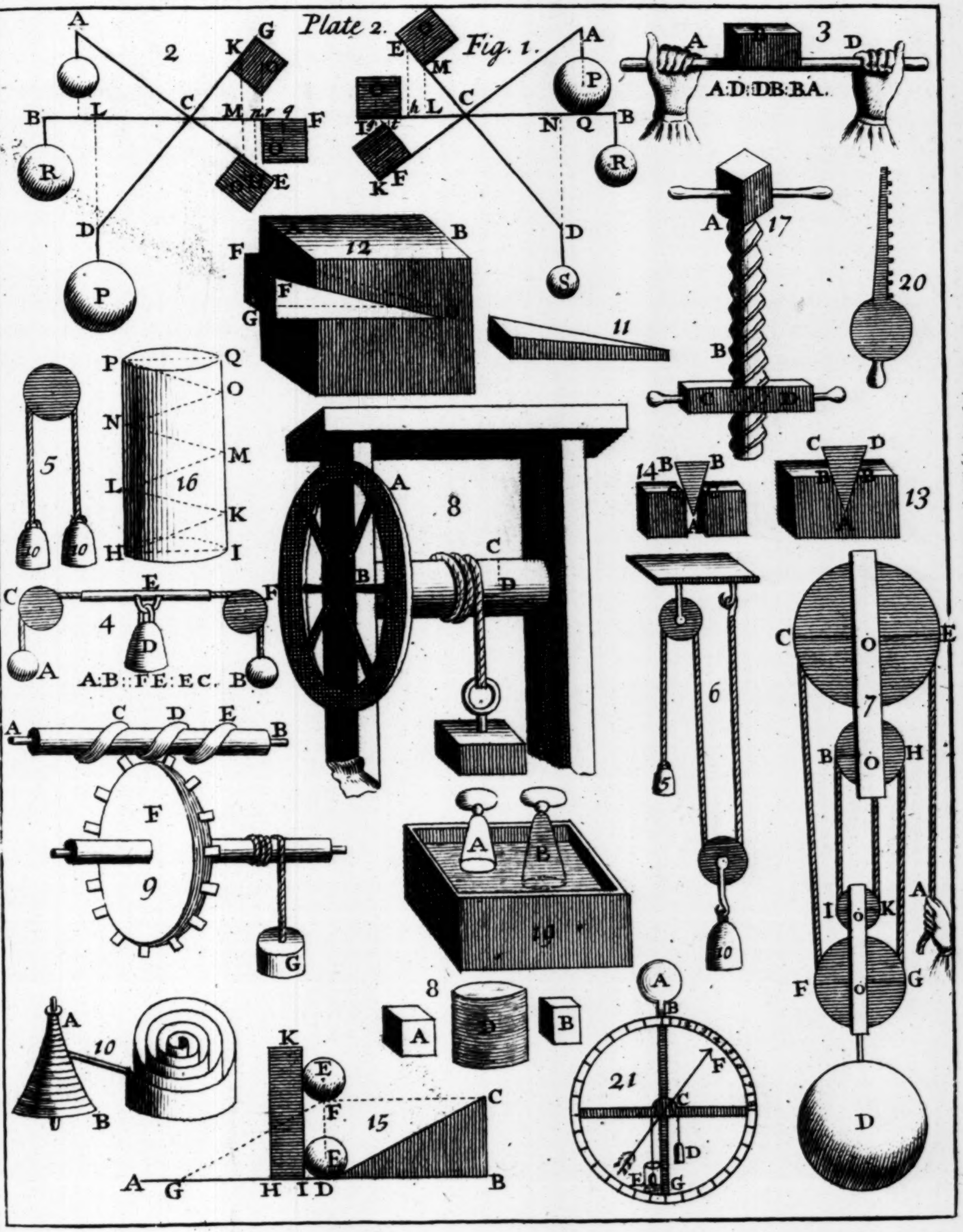
Plate 2.
Fig. 1.
A:D::DB:BA.
A:B::FE:EC.

Plate. 3.

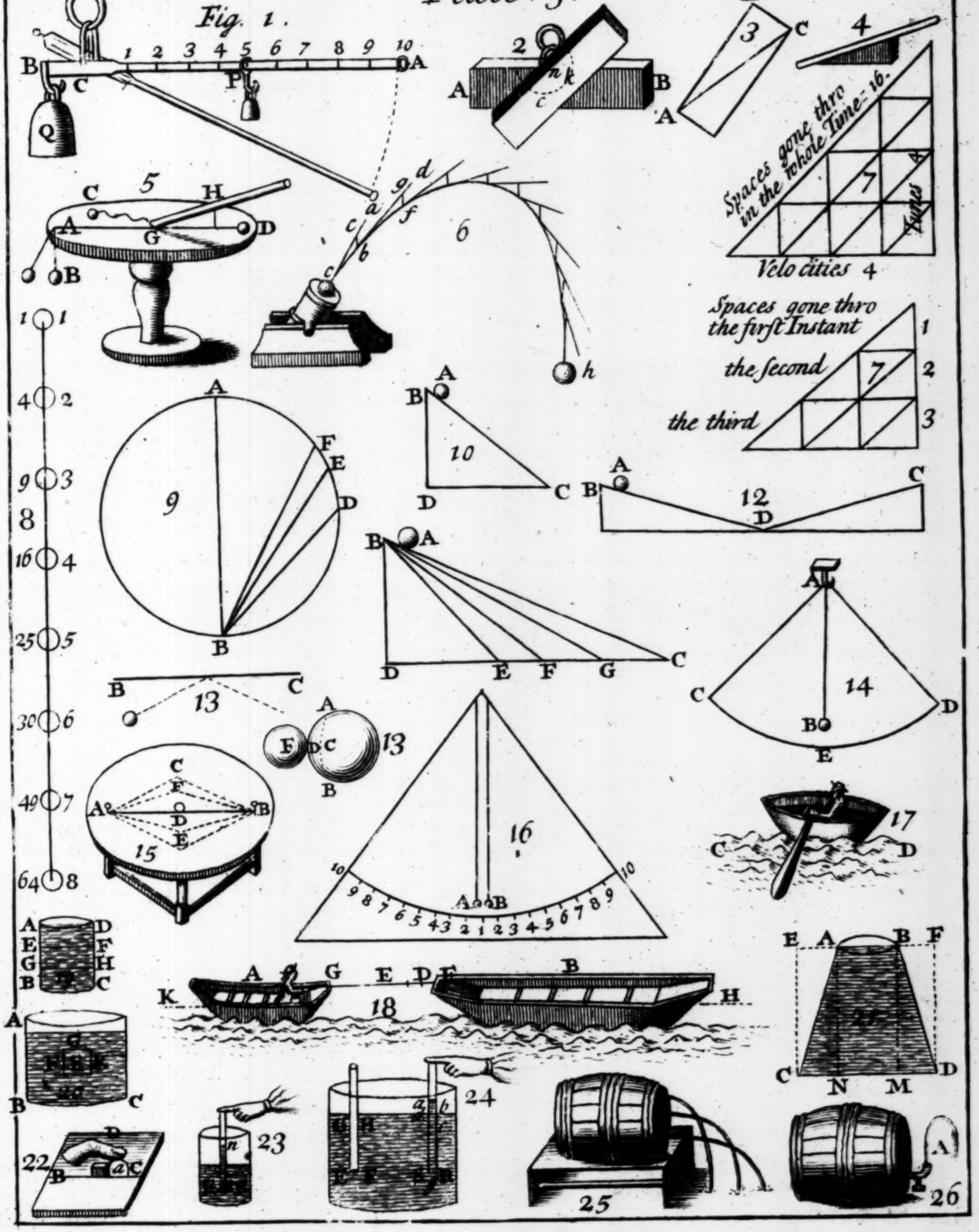
Fig. 1.
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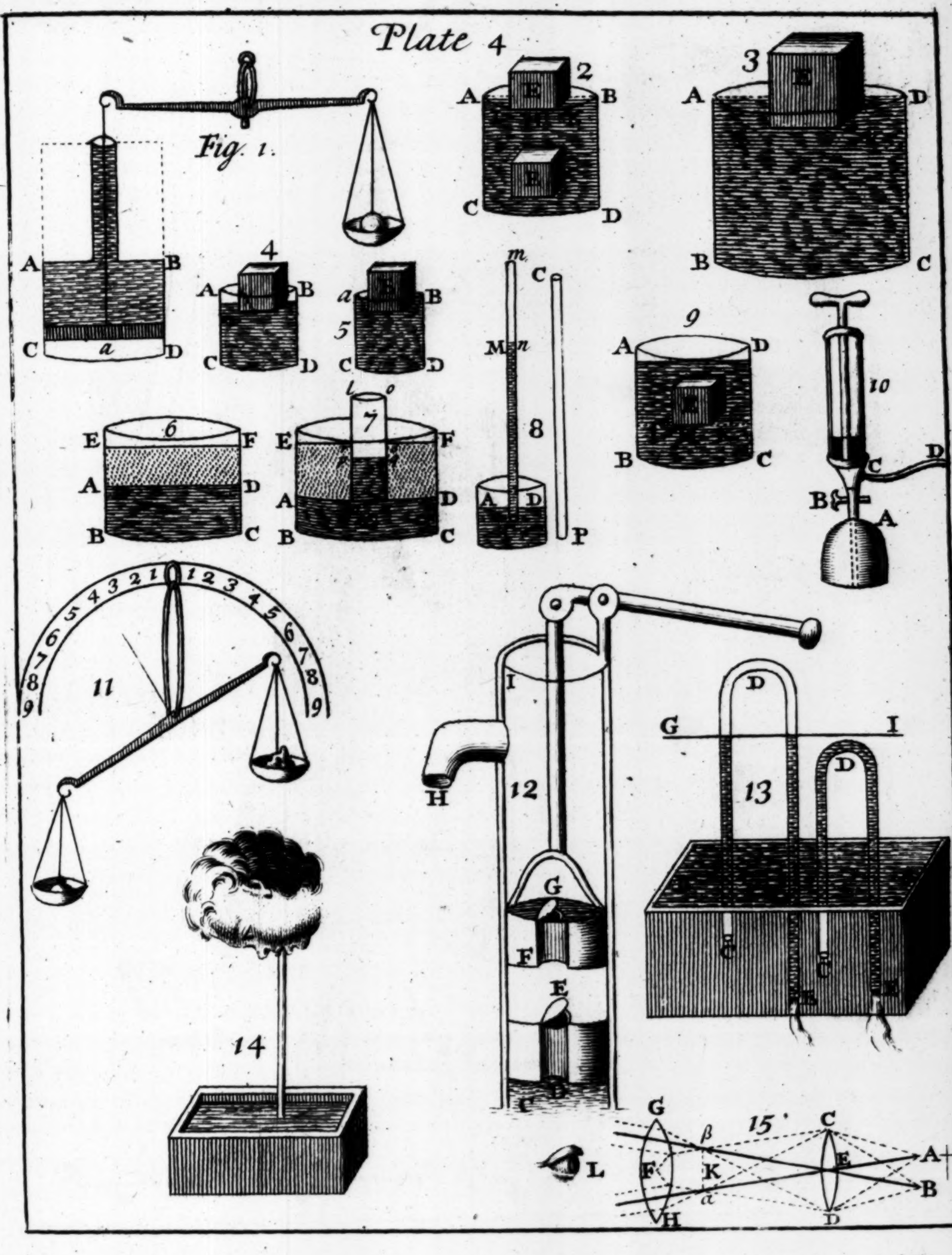
Plate 4
Fig. 1.
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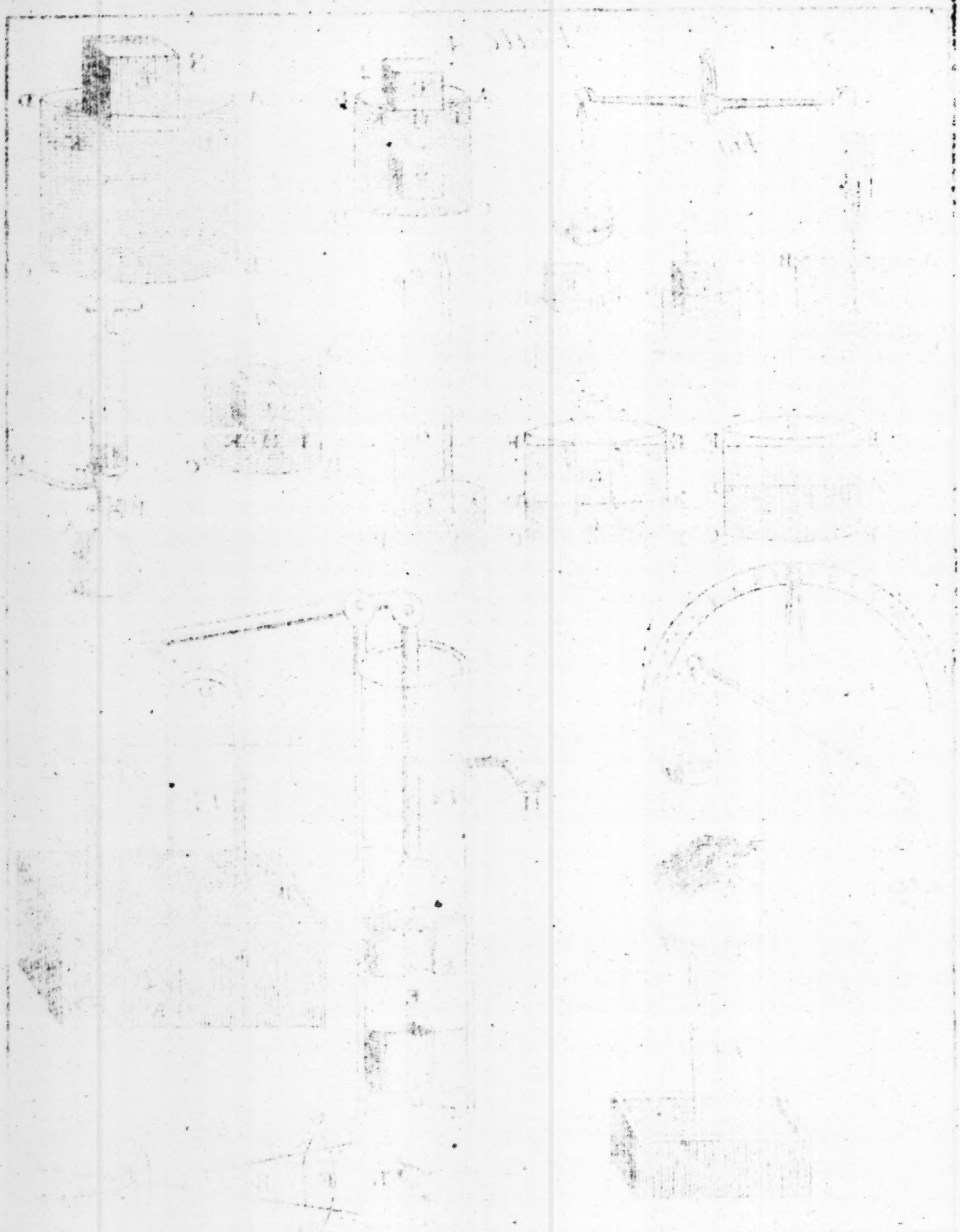

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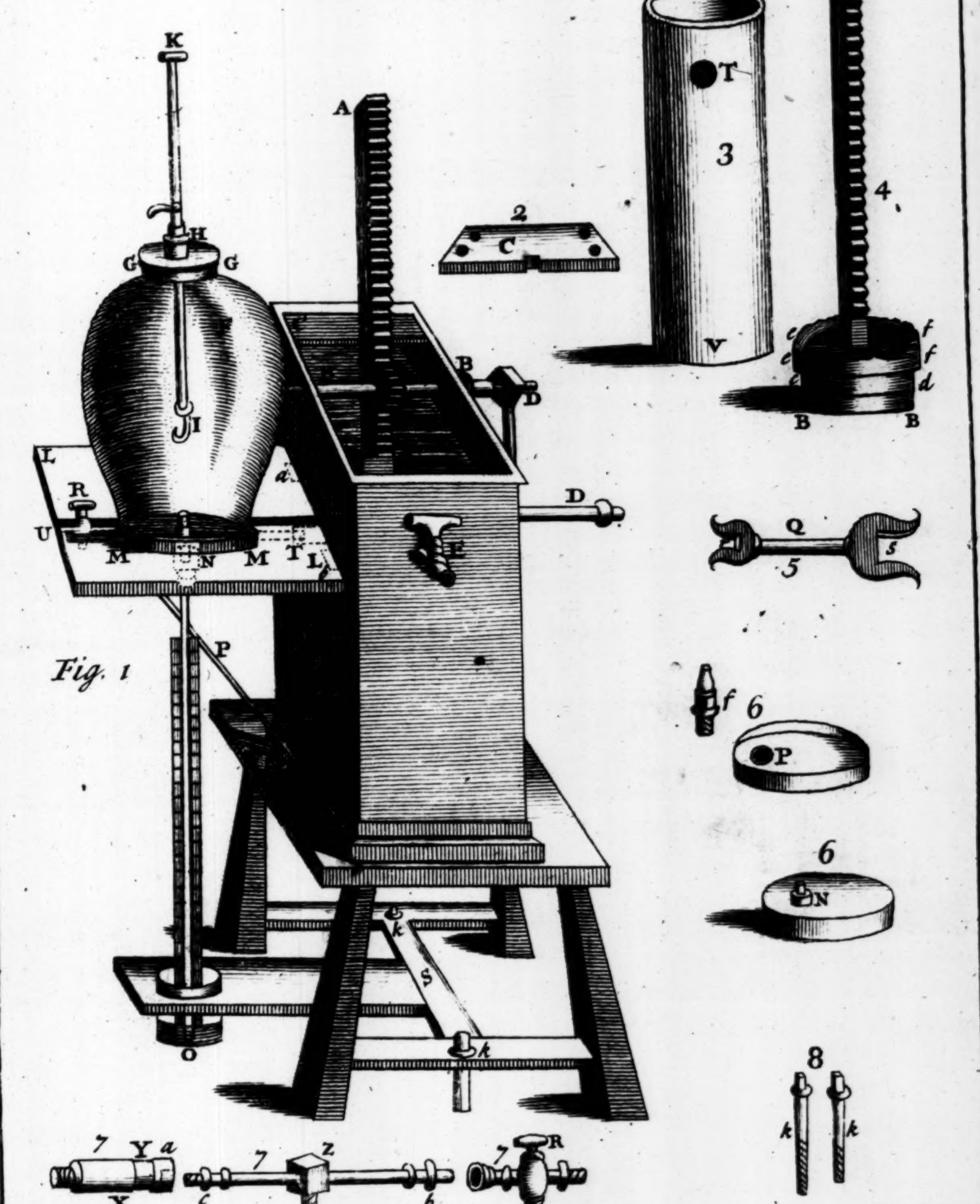

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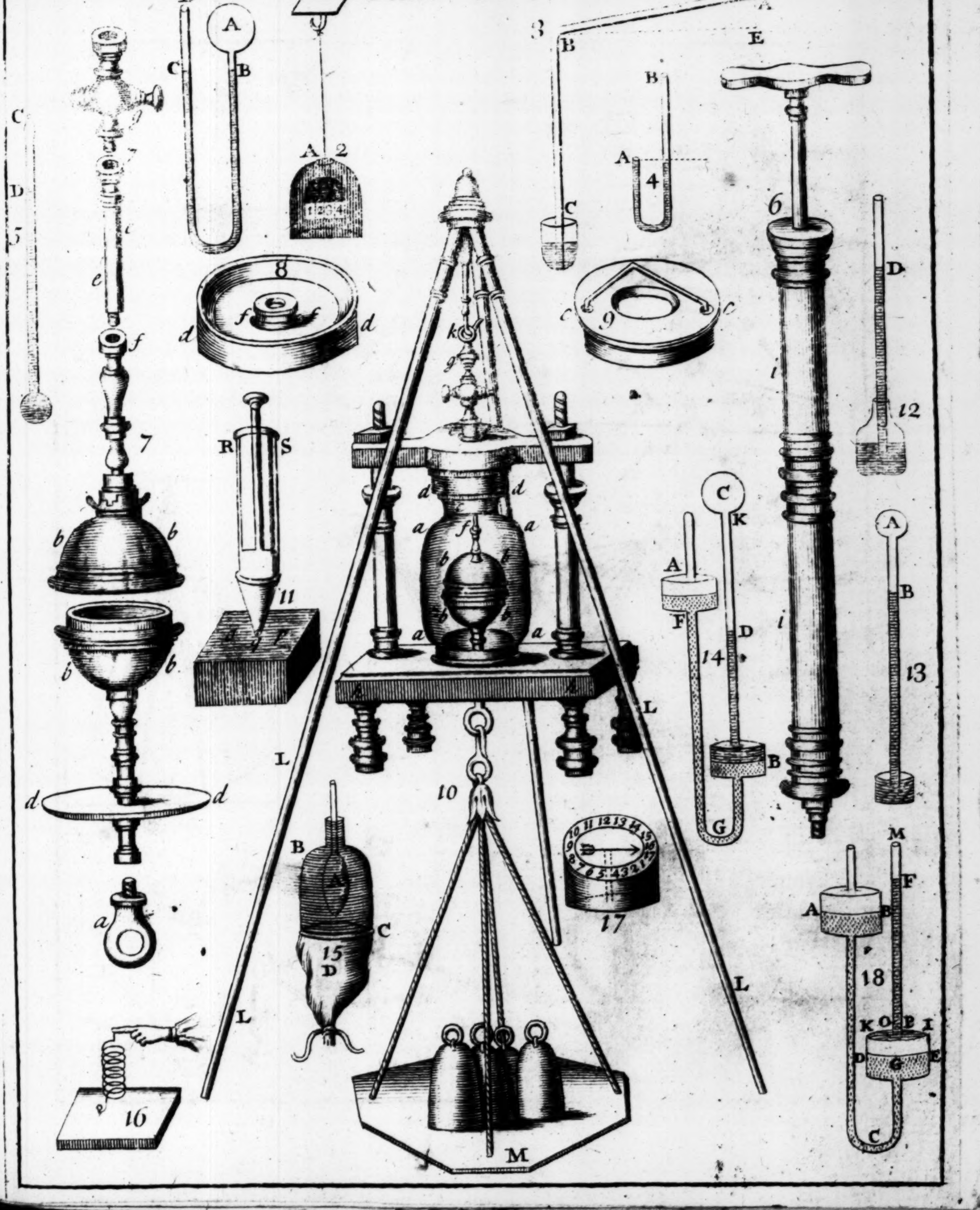
Plate 6



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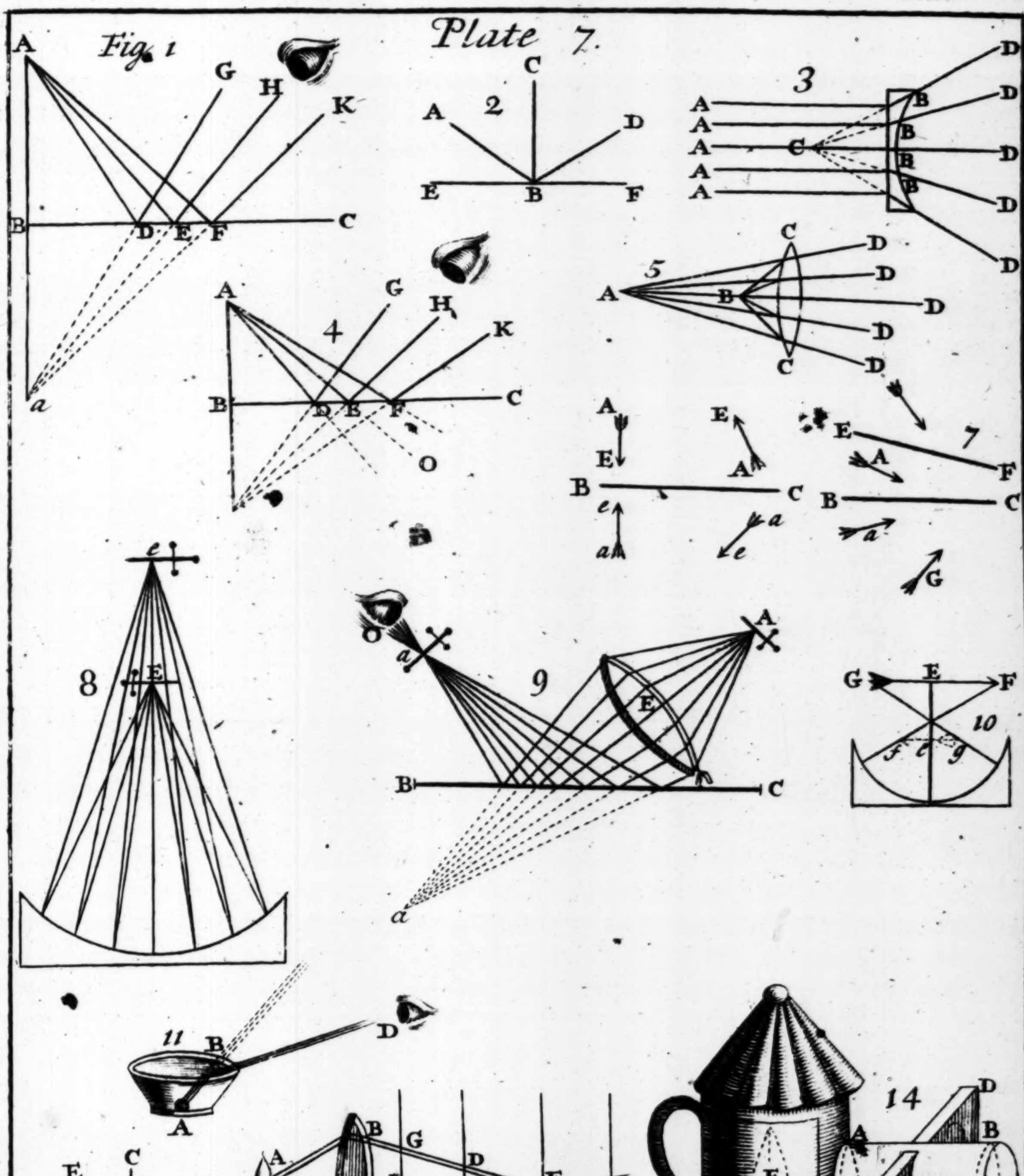

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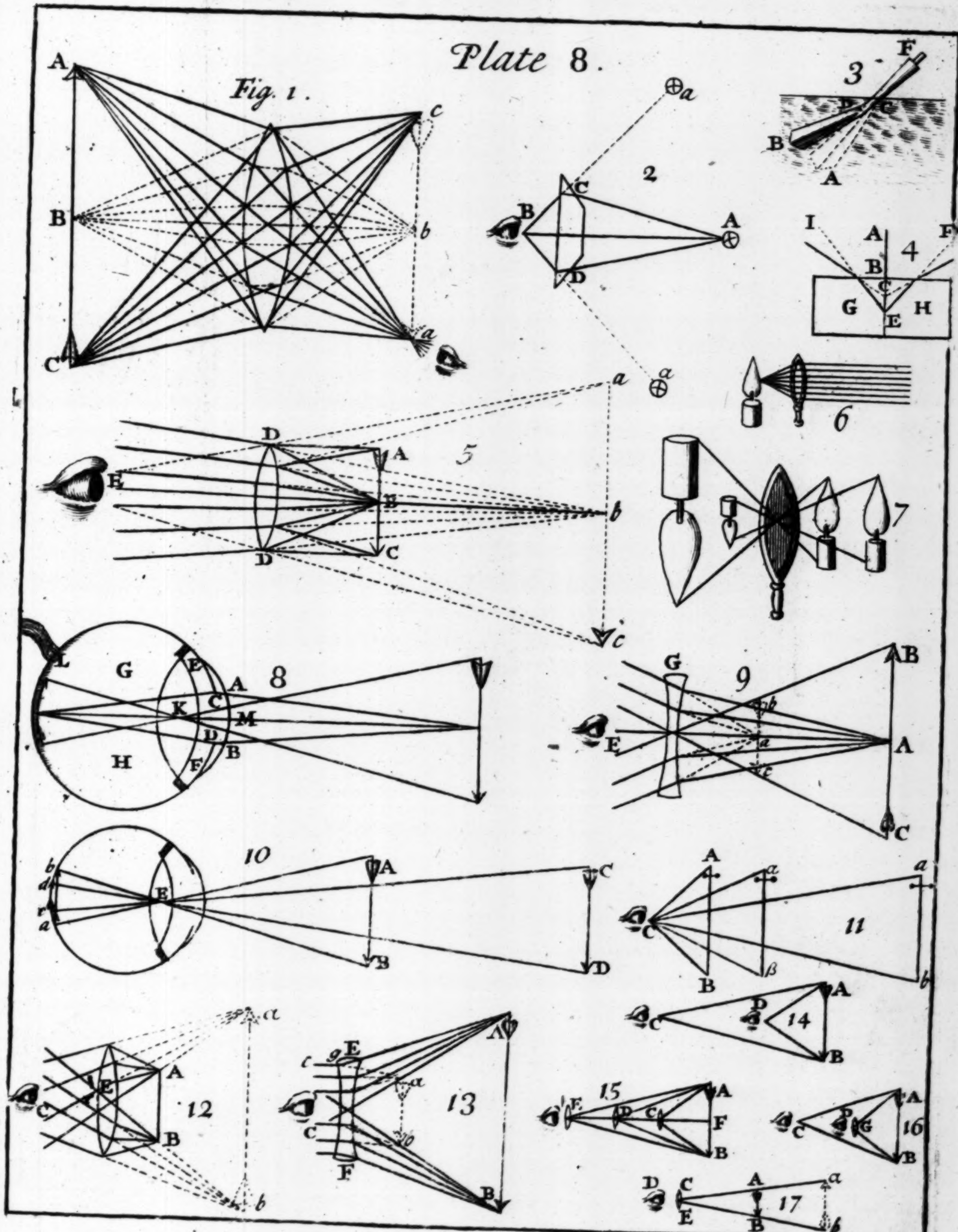

Plate 9.

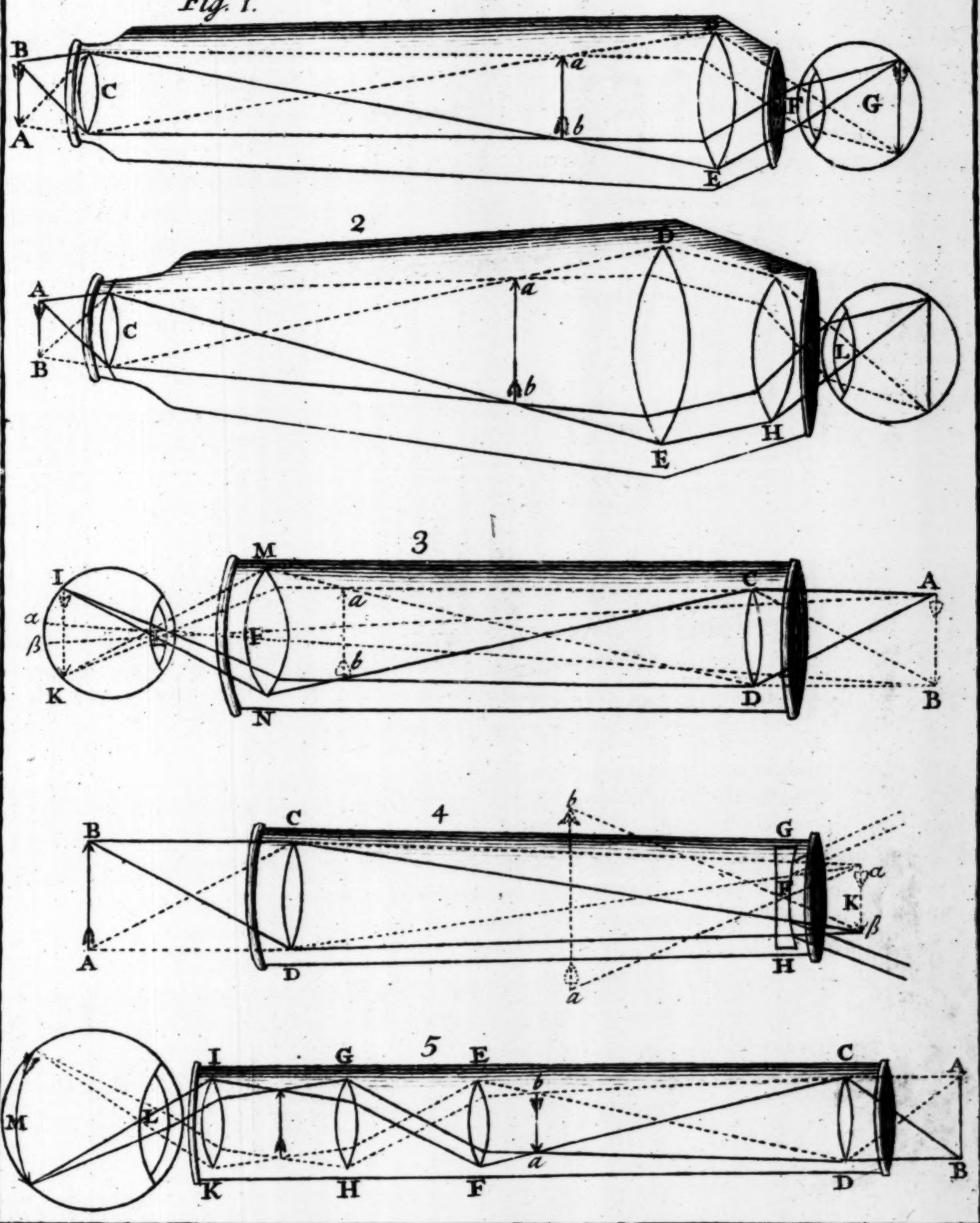

Fig. 1.
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Plate 9.

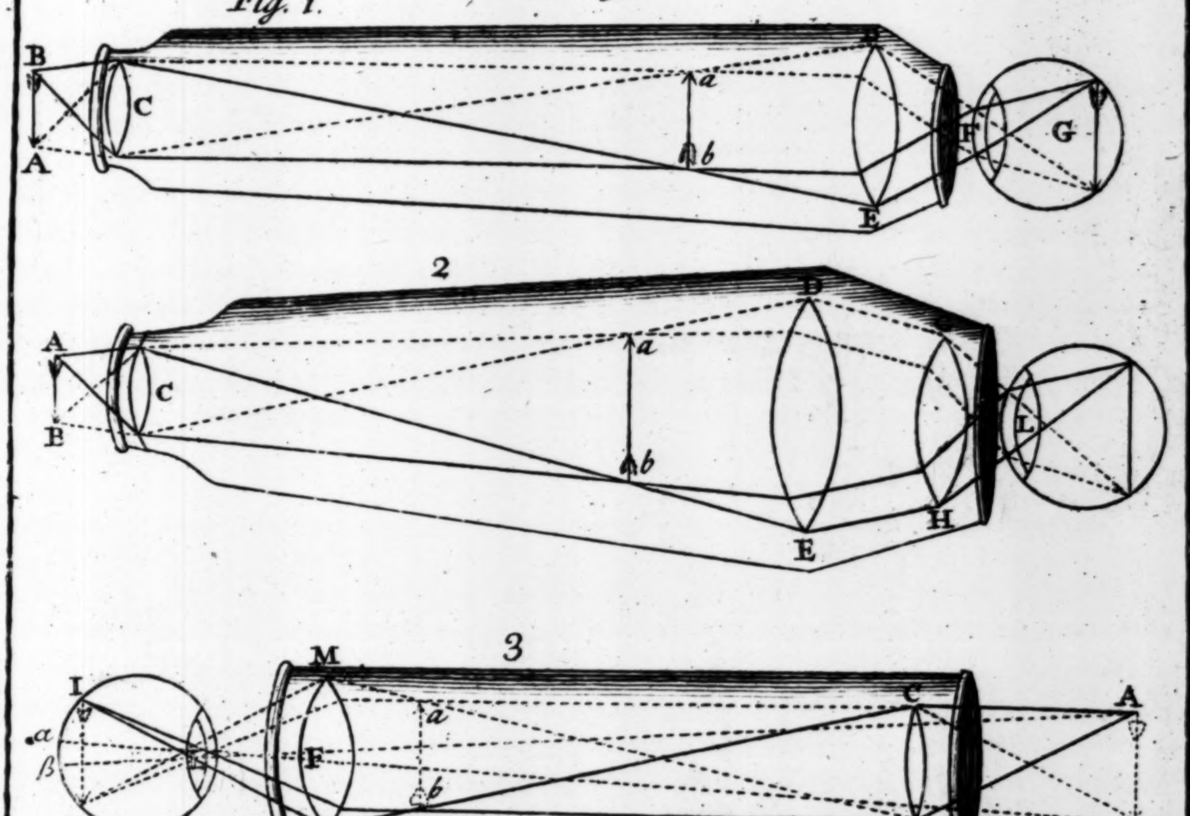

Fig. 1.
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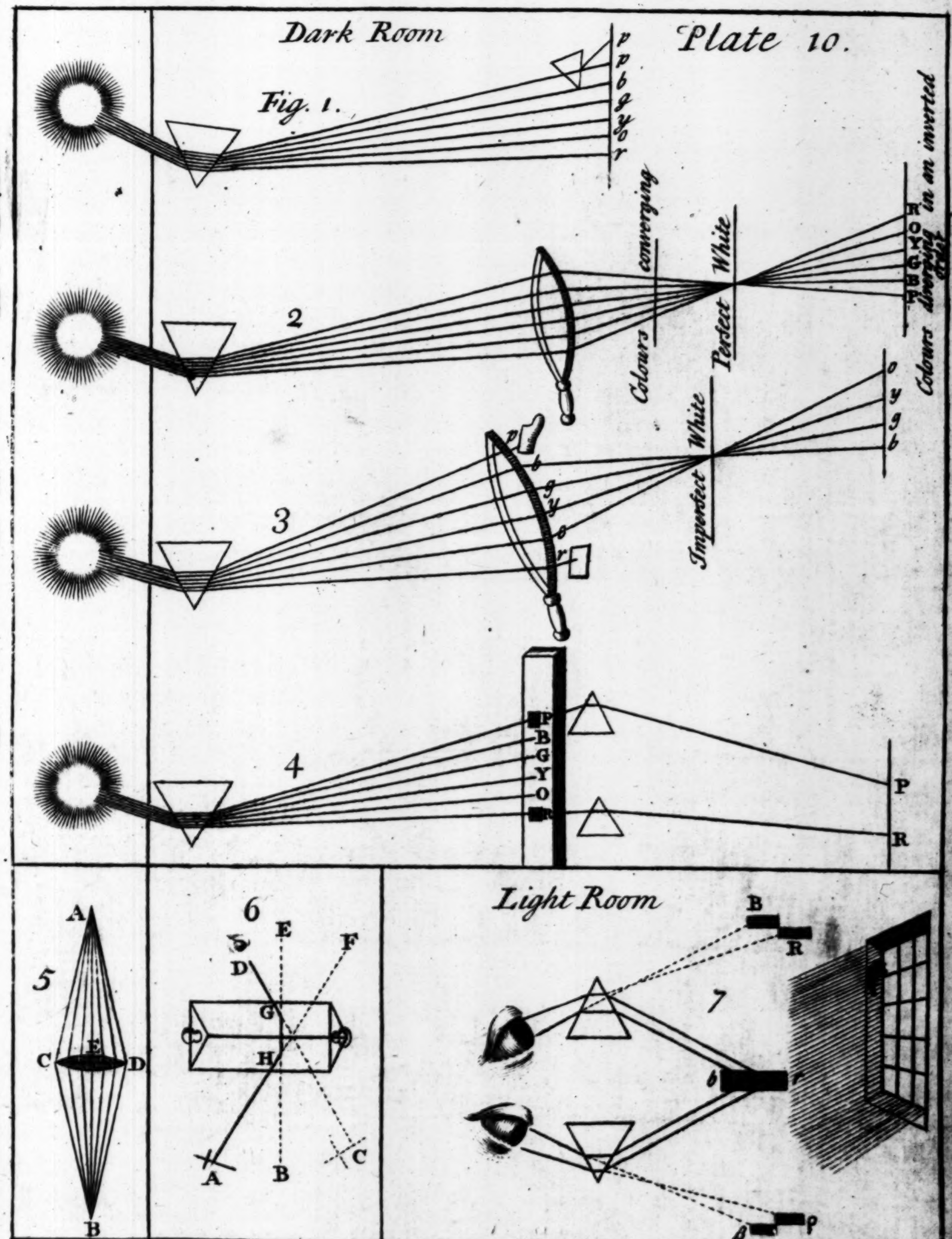

Dark Room
Plate 10.
Fig. 1.
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y
o
r
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Colours converging
Perfect White
R
O
Y
G
B
P
Colours diverging in an inverted order
3
Imperfect White
o
y
g
b
4
P
B
G
Y
O
P
R
Light Room
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C
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B
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F
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H
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r